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Small Machine Shop

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Starting a Small Machine Shop

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FIRST EDITION
SECOND IMPRESSION

New York: Toronto: London

McGRAW-HILL BOOK COMPANY, INC.

1948

STARTING A SMALL MACHINE SHOP

PRINTED IN THE UNITED STATES OF AMERICA

PREFACE

Starting a small machine shop involves more problems than most mechanics realize. Many skilled men with wide experience and with the desire for a machine shop of their own do not always understand that much more is required than the ability to handle any job that comes along.

Men with an urge to own and run their own shops have laid the foundation for some of our largest machine-building plants. They have helped build our machine industry to its present large and important position. More such men are needed because new ideas can frequently be tested and developed in a small shop better than in a large plant with a wide diversity of interests.

This book is written to help men who want to start a small machine shop. It tries to set forth the different problems that must be considered and to show how they have been solved by others. It considers the location of the shop, the selection of machine equipment with regard to both cost and efficiency, the shop layout, managing the work and the employees when the shop grows beyond the one-man stage, and how some shops have handled special work with limited equipment.

It is believed that these suggestions will prove of value in starting any small machine shop.

FRED H. COLVIN

NEW YORK, N. Y.
January, 1948

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CHAPTER I

STARTING A SMALL SHOP

Many servicemen have come back with the idea of starting a small shop of their own. This desire may be based on their prewar experience or on skills acquired while in the Army or the Navy. In either case there are many things for them to consider before venturing their savings, or committing themselves to loans obtained for this purpose. They of course realize that two things are essential to success in this or any other line of work: the ability to get business and to make it pay after it is secured.

No matter just what kind of shop they have in mind, many of the same problems must be considered. Whether the work is to be in the line of servicing radios, washing machines, or other household appliances, or in repairing automobiles or farm machinery, the selection of a good location is important. If custom is to depend largely on the passer-by, the shop must be where there are "passers-by" to see it. If custom is to be built largely on the basis of dependable service at a fair price, in a town where the owner is well known, the exact location is of less importance, as a good proportion of the work may come to the shop in any case. But the cost of getting and returning the work, both in time and in

transportation, must be considered before locating away from the business center.

The use of a truck to collect and deliver work, as well as to pick up supplies for the shop, must be calculated to include the wages of a boy or man, as well as the cost of operating the truck itself. These costs must be balanced against the difference in rent between a shop in the business district and one in the suburbs. This question of rent must be considered even if you own the shop as it must then include the taxes, insurance, and other expenses that are paid by the landlord, if you rent the place.

It may take longer to build up a paying business in the suburbs and so delay the day when the shop can begin to show a profit. The saving in time because of being near supply houses, as well as near customers, may make the business center worth more than the additional rental.

Shop Location.—Locating the new small shop is not always a matter of choice on the part of the one who is to start it. He must choose between the most available locations and buildings unless he can pick a lot and build his own shop to suit. Location often depends on the sort of building that is suitable and where it happens to be. For a jobbing shop the best location would be as near as possible to the center of the district from which work is likely to come. This is not only on account of getting what work is needed but the cost of handling it from the customer to the shop and back again.

Rents should be considerably lower away from the center of a town, and this frequently happens to

be where the customers are located. But if the bulk of the work is to come from the town itself, as in the case of general repairs of vacuum cleaners, sewing machines, and household appliances, the saving in rent may be offset by the cost of trucking back and forth. Then, too, the question of supplies should be considered as suppliers are frequently located near the center of a town. In most cases it will be necessary to balance one advantage against another.

Lighting and heating are two other important points to be considered. Both are necessary to get economical work. Men cannot work well in a cold shop nor can they do accurate work without sufficient light of the right kind. If electric current is available, the lighting can be easily taken care of by using the proper lighting fixtures and the right amount of light, where it is needed.

Ventilation can be taken care of with a few electric fans placed in the right locations, which can move the air without making a direct draft on the men. In making accurate fits the difference in temperature caused by the direct blast of a fan might make more difference than would be imagined.

Selection of Machines and Tools.—The selection of machines and tools depends largely on the kind of work to be done. But, no matter what the work, drill presses and engine lathes are sure to be necessary, as well as a grinding stand for sharpening tools. If possible, a medium-sized shaper should be included, together with a medium-sized milling machine for average work. The sizes and types needed will

depend both on the work expected and the experience of the man or men who are to use them.

Usual repairs on domestic machinery do not require large machine tools. A few high-speed bench drills with a capacity of ¼ in. will be useful in most lines of small work. There should also be one machine capable of handling drills up to 1 in. Engine lathes with from 8- to 16-in. swing will handle a large variety of work, and an 18- or 24-in. shaper will be very useful in any shop. In milling machines both hand and power feed are very convenient. Oddly enough, the hand machine is likely to be more useful in small manufacturing than in repair work. A medium-sized universal milling machine will handle many kinds of work and be of great value.

Grinding machines help in many kinds of work, but they run into considerable money and may not be necessary until the small shop has grown into one of considerably larger size. A good motor-driven portable grinder on the tool block of an engine lathe can handle a lot of cylindrical grinding. The same grinder on the head of a shaper can pinch-hit for a surface grinder on many jobs. Both internal grinding and thread grinding can also be done on the engine lathe with the same attachment.

There are wide differences of opinion as to whether to buy new machines or those which have been rebuilt after use in other shops. Whether you buy new machines of a cheaper price, or new machines of better known makes that have been rebuilt, they should be checked as to their condition by some good mechanic. If the serviceman can do this, so much

the better. For lathes and some other machines there are standard tests that can readily be obtained.

The service given by some of the low-priced machines during the war, even in shops accustomed to the best, indicates that many of the machines formerly thought to be in the amateur class, can be very serviceable. This was particularly true of drill presses and engine lathes in the smaller sizes. Unless good used machines of the so-called "standard" makes can be obtained at a reasonable price the other class of machine may be the best buy.

In spite of prejudices against rebuilt machines in some shops, many of them are excellent investments. Many shops that are prosperous today could not have been started except by utilizing old machines, frequently in bad condition, because first cost was of prime importance. It frequently happens that a carefully rebuilt machine tool, 20 or more years old, is much better than it was when new. It may not have all the conveniences of later machines, but in the small service shop it will do as well as a new machine and at much lower cost. Those who are prejudiced against used machines should remember that all new machines are built on used machines, some of them with many years of service to their credit.

Used machines should always be bought from a reputable dealer unless the buyer is familiar enough with them to know their condition and to rebuild any parts that may be worn appreciably. By buying good used machines, or good low-cost new machines of good repute, the initial investment can be kept

low. This reduces the charges that must be made for overhead on all work done in the shop.

Although a good mechanic can do a wide variety of work on an engine lathe, especially by using milling and other attachments, it is seldom good business to do so, unless absolutely necessary. It frequently ties up the lathe when it should be used on regular work, and such attachments are usually of limited capacity. It is much better business to have a few extra machines than to have work delayed because all the machines are busy. Successful shop managers feel that they should not plan on over 80 per cent of the machines as being necessary to get the work out on time. In other words, there should be an excess machine capacity of 20 per cent. Unforeseen delays usually eat up the 20 per cent margin. Prompt deliveries, at the time promised, are among the best means of getting more business.

If your machine equipment is limited, it is a good plan to get acquainted with other shops in the neighborhood or town, and see how well they supplement each other. With a friendly feeling among shop owners or managers, the capacity of a number of shops can be combined in an equitable working arrangement that will benefit them all. In this way a small group of shops may have the use of planers, grinders, and perhaps gear cutters, although each may have a relatively small number of machines.

One small shop in Florida, with the very compact layout shown, had a 30-ton hydraulic press which handled all the force-fit work for miles around. The

press, incidentally, could be used only in good weather as it was necessary to open up the side of the shop in front of the machine in order to get at it. This shop also owned a 60-in. engine lathe which sat out in the open in the next lot. Once in a long time a job came along requiring this capacity, usually from other shops. Then they hauled a portable gasoline engine into position and ran the lathe as long as necessary.

By pooling resources in this way a number of small shops, with comparatively little equipment, can handle a lot of work that would otherwise have to be sent out of town, to some larger shop than the town affords. Such an arrangement helps the small shop to get started with a minimum outlay at the beginning.

This pooling of machine capacity can be done in various ways. The work can be done by the men in the shop housing the machine equipment, or the machines can be rented to the shop in which the order has been placed. This method has the advantage of keeping responsibility for the work in the hands of the shop receiving the order and is generally to be preferred. Such an arrangement is more apt to preserve harmony between the shops involved. If, however, the men in the shop receiving the order are not familiar with the type of machine on which the work is to be done, the second shop must consider it as an order from the first shop and handle it accordingly, charging a fair price, including profit for the work done.

The main thing is to establish and maintain har-

monious relations among the various shops, to be open and aboveboard in all dealings with each other in every way, both as to getting orders and to coveting each other's men. Wear and tear, as well as damage to machines used by men from another shop, are also to be considered. All these factors must be balanced against the division of responsibility, and this must have careful consideration.

Shop Costs and Overhead.—In this, as in all other dealings with customers or with the other shops, it is necessary to have a clear understanding of all shop costs, including labor, material, and overhead of various kinds. There is much less trouble in considering either labor or material than with overhead, as here ideas differ so widely as to make misunderstandings much too easy for comfort. Overhead due to rent, insurance, taxes, and maintenance of the shop building is a fairly easy matter to calculate. These must also be considered even if you own the building. Machine overhead is much more difficult to determine. It must be based on the first cost of the machine, the cost of its upkeep during its life, depreciation charges to ensure its replacement when worn out, the floor space it occupies, and probably the cost of the power it requires.

In many cases it is the cost of machine overhead that affects the charges to be made for work of different kinds. Even with men paid at the same rate it is plainly unfair to charge as much per hour for a man at the bench as for a man running an expensive

machine. This is why the old method of charging a uniform overhead for all work in the shop is not businesslike or fair in any way. This is why it may be necessary to charge $5 an hour overhead for an expensive machine and only $1 an hour for a bench job, or for one on an inexpensive drill press.

The old method of charging a fixed percentage, based on direct labor, was decidedly unbusinesslike. In many ways it is misleading to use direct labor cost as a basis for overhead. For years shops have placed a figure of 150 per cent of direct labor as the maximum to be considered as good business management. The foolishness of such a basis is seen when we realize that, as we increase machine efficiency, the labor cost must go down. In highly mechanized plants that are most efficient, the overhead may reach 400 per cent of direct labor, as most of the work is done by the machines.

A flat rate of overhead, based on direct labor, favors the work that requires the use of an expensive machine and overcharges the job that can be done on the bench or on a low-cost machine. Overhead charges will be discussed in detail later in this volume.

In most shops only skilled men are put on high-priced machines so that a rate per hour can be set on each machine which will cover the wages of the man as well as the machine overhead. It must also be remembered that the general overhead must cover the average time when the machine is idle as well as when it is in use, because interest on the investment goes on whether the machine is running

or not. This is particularly necessary because many large machines are used but seldom, but they are necessary to handle the occasional job that requires their use. No matter how seldom they are used, they represent idle capital and take up valuable floor space. This adds to their overhead which must be paid for by the job that requires their use. This is one reason why we find so many of the larger machine tools with years of service to their credit. They have been bought secondhand from shop to shop in order to keep the first cost and overhead as low as possible. They must of course be kept in good condition for turning out accurate work. But it is of little importance whether they have all the latest conveniences of modern machines as they are used such a small percentage of the time. Machines of large capacity run into large investments, and new ones can usually be afforded only by shops where they will be used a large percentage of the time.

Another item that is debated in many small shops is the charge to be made for materials used in the work. Should they be charged at cost or should a small charge be made for purchasing and handling them?

It seems to be necessary, and entirely legitimate, to make a charge for purchasing and handling, for several reasons. The cost of ordering both in time required and clerical work necessary, of going after the material when that is necessary, of handling the material in the shop, the cost of bookkeeping, if any, and the capital tied up in the stock for varying

lengths of time, all add to the cost of doing business. Although a few customers may consider this an unfair charge, it is easy to show them that it is justified, and the necessity for it. Few of them would prefer to spend the time to buy the material and deliver it to your shop. It is a good plan to offer them that alternative. Then, too, it is usually necessary to buy more material than is needed for a single job. This material must be paid for, handled, and stored waiting for the next job on which it is required, all of which adds to the cost of running a shop.

As to the equipment that may be required, only a few machine tools need to be considered. On a large variety of work it will be necessary to have oxyacetylene cutting and welding equipment as well.

CHAPTER II

SELECTING MACHINES AND TOOLS

Once the location of a shop and its size have been decided, the kind of machines to buy and their location in the shop become important questions. Their location must be given careful consideration although in a small shop this is not so important as many seem to think. If the shop is to build a regular product, then the machines should be arranged so that the work passes from one operation to the next with as little handling as possible. In a job or repair shop you never know just what the next job is to be or what machines the first operation will require. One general rule, however, is to have the cutting-off saw, if there is one, near the place where the raw material is kept so that a minimum handling of stock is required.

The kind and size of machines to buy depend on the work to be expected and on the amount of capital to invest. In most cases the first investment should be kept low so as to retain as much working capital as possible. One great error which has led to many failures is to spend so much money on shop equipment that there is not enough left for working capital. This fault is too common with mechanics who, although they know how to manage the running of machines, have had little or no experience with the financial end of any business.

Work may not come in so rapidly as anticipated. It may take longer than you figured in getting yourself known and work started to come your way. In the meantime the bills for machines and materials come due, and payday for the men, or for yourself, comes around with discouraging regularity. Although it is essential to have enough equipment to handle the average job that comes your way, it is better to hire a machine in some other shop for a while than to run short of funds at the bank. After buying enough machinery and tools for your minimum requirements, it is usually best to avoid buying more until payments for work done, as well as new business, begin to come in with fair regularity. Better spend a little more time on a job with the machines you already have than to spend more than you can afford for a more efficient machine, until you have the capital to spare.

Banking Problems.—This may be a good place to give a piece of advice as to banks and bankers. One very successful manufacturer who began in a small way followed the advice of a banker friend in the following manner. He was making plans for an expansion that would require a substantial loan from the bank. Although he still had a good bank balance, he borrowed \$2,000 for 90 days and paid it back promptly. A little later he borrowed \$5,000 and repaid that a few days before it was due. When he was ready for his real expansion, he had no trouble in borrowing the funds he really needed, which ran up to \$15,000. According to the banker, "It pays to establish credit by borrowing and re-

paying promptly." If you wait until you are in dire need of funds, it may be difficult to get the loan as you may not be able to make a good showing in applying for a loan at such a time. But if you have received a few loans and paid them promptly, you are not likely to be refused even when you need a considerably larger amount.

The credit you have established is worth more than the interest you have paid on the loans. It pays to keep enough working capital available even if you have to wait before purchasing a machine which could save you time and money, unless you can make very favorable arrangements as to its purchase. In many cases you can arrange for time payments which let you pay for the machine as it earns money for you. Here is another case where you can afford to pay an interest charge in order to avoid letting your working capital get too low. Watching the bank balance and being sure to keep enough surplus to meet unexpected demands will help in carrying you to the point where a sufficient volume of business is assured.

General Machine Work.—Generally speaking, all kinds of machine work require drilling, boring, and turning, and the shaping of flat surfaces. This means the use of drilling machines, lathes, milling machines, shapers, or planers. The size and type of each machine depend largely on the kind of work to be done. Although fairly small holes can be drilled on floor-type vertical machines, a good bench drill is usually more convenient for holes under

¼ in., unless it must be drilled in a piece too large to be handled in a bench machine.

As speed of the drill is very important in making small holes, this requirement should be carefully noted in buying a machine of this type. For very small holes, such as 0.010 in. and smaller, the drill spindle should be capable of speeds up to 10,000 r.p.m. Some of these machines will drill holes as small as 0.002 in. in diameter at the top speed, and it is necessary to have the drill clear itself and prevent drill breakage. Even in this case the drill must be well supported. A drilling machine of this kind should not be used on drills over ⅛ in. in most cases. Some of the better bench drills will handle drills up to ⅝ in. but should be generally used for work around ¼ in.

A good floor-type machine, formerly known as the "upright drill," that will handle drills up to 1 in., or perhaps 1½ in., will take care of the great majority of drilled work in the average shop. Drilling can be done in the lathe by running the drill in the lathe spindle or by revolving the work on the face plate or in a chuck, and holding the drill in the tailstock. But in most cases it is advisable to use a floor-type drill.

It is well known that extreme accuracy should not be expected of drilled holes. For unless the drill point is ground very accurately, with both lips of exactly the same length and angle, the drill will cut larger than itself in most materials. Nor is the hole always perfectly round. With care, however,

drilled holes can be made accurate enough for most purposes. For extreme accuracy holes are either reamed or finish-bored with a single-point tool.

Engine lathes probably come nearer to being all-round machines than any other in the shop, but they are most efficient when used for turning, boring, and cutting threads, both inside and out. Lathes with from 8- to 16-in. swing will be found useful on small and average work. One lathe in the shop should have a taper attachment if possible. For although tapers can be turned by setting over the tailstock and bored by using a compound rest, the taper attachment is more satisfactory for both kinds of work.

If only one lathe is included in the first shop equipment, it should probably be a 14- or 16-in. swing. This can handle work as small as is likely to be encountered, and 16 in. gives considerable leeway on good-sized work. If there is much small work, an 8-in. lathe with legs or a bench lathe of 6- or 8-in. swing will be very convenient and save time.

Where the average work can be handled on a 16-in. lathe but where an occasional job requiring a 24-in. lathe is apt to come in, the use of raising blocks under head- and tailstock may be advisable. By raising the head- and tailstock 4 in., a swing of 24 in. is secured, and this will accommodate a wide variety of work. In this case it is of course necessary to raise the tool block 4 in. so as to bring the tool to the center of the work. Although stretching the capacity of a lathe does not add to its rigid-

ity, it will handle occasional jobs and save buying a larger one.

Machining Flat Surfaces.—For machining flat surfaces a milling machine or a shaper is necessary. The small shop will find the shaper less expensive in most cases, as it uses tools similar to those in the lathe; the milling machine requires quite a variety of cutters for different work, which are expensive in comparison. An 18- or a 24-in. shaper will generally handle the work in a small shop and will be more convenient on small work than a shaper with a longer stroke. In fact, the 7- or 8-in. shaper is found to be very handy on much of the work that comes into the small shop. These small shapers are usually of the bench type and are not expensive.

If you are likely to have to make special taps and reamers and an occasional gear of odd size to keep repairs going in some neighboring shop, a milling machine is almost a must. For although it is possible to flute taps and reamers in a shaper and even to cut a special gear in an emergency, the milling machine is better in almost every way for this work.

The many uses to which a universal milling machine can be put make it more desirable for the small shop than a plain machine. With indexing centers and a dividing head it is possible to do many kinds of jobs that may be needed in a hurry. Special gears can be cut in this way but of course require special cutters for the gear teeth. For repair work it is possible to use the same cutter over a wider range of teeth than where the shape of the tooth is

of more importance. The range of gear teeth that can be cut with a set of standard gear cutters is shown in Table 1.

TABLE 1.—BROWN AND SHARPE INVOLUTE GEAR-TOOTH CUTTERS

No. 1	will cut wheels from 135 teeth to a rack.
No. 1½	will cut wheels from 80 teeth to 134 teeth.
No. 2	will cut wheels from 55 teeth to 134 teeth.
No. 2½	will cut wheels from 42 teeth to 54 teeth.
No. 3	will cut wheels from 35 teeth to 54 teeth.
No. 3½	will cut wheels from 30 teeth to 34 teeth.
No. 4	will cut wheels from 26 teeth to 34 teeth.
No. 4½	will cut wheels from 23 teeth to 25 teeth.
No. 5	will cut wheels from 21 teeth to 25 teeth.
No. 5½	will cut wheels from 19 teeth to 20 teeth.
No. 6	will cut wheels from 17 teeth to 20 teeth.
No. 6½	will cut wheels from 15 teeth to 16 teeth.
No. 7	will cut wheels from 14 teeth to 16 teeth.
No. 7½	will cut wheels from 13 teeth to 14 teeth.
No. 8	will cut wheels from 12 teeth to 13 teeth.

The eight cutters represented by the whole numbers constitute the regular set of cutters generally used for each pitch of tooth. The half numbers increase the set to 15 and give teeth which are theoretically more correct. In some work special cutters are used for each gear but the 15 cutters in a set offer all that most cases require.

There are also good milling attachments for engine lathes that do quite a variety of work. It may be well to consider one of these if capital is limited.

A grinding stand for sharpening lathe and other tools is one of the first requirements in any shop. This will handle tools for the lathe and shaper and can be used to sharpen drills if great care is used to get the proper shape and length of each lip. Milling cutters should not be sharpened except with some special holding device similar to that provided on

regular cutter grinders. The cutter must be held so as to revolve true on its bore and permit the grinding of the same amount from each tooth. Unless this is the case, all the work of milling will be done by a few teeth, which will become dull very quickly, and the work of milling will take much longer than it should. It is possible to make a holding device in which the milling cutter revolves on its arbor and to have a stop, or finger, so that each tooth is held in the same position with relation to the grinding wheel. Only in this way can the cutter be made to cut uniformly with all its teeth. A regular tool grinder is desirable if one can be had at a price to come within the budget. Without the milling machine this will be needed only for reamers and similar tools. This is one reason for picking the shaper instead of the milling machine if the budget available for machine equipment is limited.

An oxyacetylene cutting and welding outfit is almost as necessary in the average shop today as the lathe or drill. It should have enough tips to handle a good variety of work. And at least one man should be trained to use it efficiently on the various kinds of work that are likely to come into the shop. A clever torch operator can do almost unbelievable things in both cutting and welding and can save a lot of money for both the customer and the shop itself. Flame cuts can be made with a surprisingly narrow kerf, or slot, and with smoother edges than are usually found.

In welding, also, a good operator can leave a weld that is quite smooth and clean and that requires a

minimum of dressing either by grinding or machining when the surface must be finished. Even on an unfinished surface it pays to have the weld look smooth and attractive, as it indicates that the shop where this was done knows its business. Such things are frequently the best sort of advertising and help to get more work.

Good benches are as necessary as machine equipment. Those with steel legs or underframes are usually more satisfactory and probably cost about the same. They should have drawers for some tools, but it is well to watch these drawers and see that they do not become hiding places for tools that should be kept in the toolroom, or tool closet, or wherever the general small tools are kept. Unless careful watch is kept from time to time, bench drawers usually contain a wild and varied collection of things that do not belong there.

Files should not be kept in drawers but in racks on or back of the bench, so they will not touch each other when not in use. Files are often damaged more by contact with other files, or with other tools, than in actual work. There should be plenty of files, selected for the work they are to do and kept for that kind of work. Rough or bastard files should not be used where second-cut or smooth files will do better work, nor should this be reversed. Although files are used less than formerly in most shops, they still play an important part in shopwork of nearly all kinds, particularly in small shops doing repair work.

All filemakers publish instructions regarding the

selection and use of files, and it is well to have several of these little booklets around the shop for men or boys who have had little experience in their use. Filing round work in the lathe was formerly practiced much more than at present, but it is a doubtful practice where round work and good fits are necessary. In spite of this, there are places where it is still considered good shop practice on some kinds of work and special files are made for it. Unless the right file is selected, this work is hard on the tools and may run into considerable cost.

It is impossible to suggest a collection of files that would be best for all shops. It is far better to get some good file salesman to look over your work and suggest the kinds and sizes of files that will give the best satisfaction.

As it is doubtful if the average small shop will invest in a milling machine at the start, it may be well to consider the use of a milling attachment on the engine lathe, when the job requires work of this kind. This is not a substitute for a good milling machine, but it may help out on some special work until the time comes when a milling machine will be a paying investment. The use of such an attachment is shown in connection with lathe work. Although it is possible to make some such attachment yourself, and many have done so, it will probably be much cheaper and more satisfactory to buy one already on the market.

One attachment that will be found useful in any job shop is what was formerly known as a "tool post grinder" and is still called by that name in

some places. It is really much more than the old attachments that originally bore the name. The old ones were belt-driven from an overhead drum, by a small round belt that traveled along the drum as the grinder was fed along the work. The modern tool block grinder has its own motor and is a very satisfactory adjunct to the lathe in any but the largest shops.

With a grinder of this kind the lathe can be used as a cylindrical grinder on work where the finish on round work should be made in this way. It has plenty of power to remove as heavy cuts as should be taken on work of this kind and will pay for itself in a short time. The same portable grinder can be used on either the milling machine or the shaper for finishing flat work. When used in the shaper, the travel of the shaper ram must be slowed down to a lower rate than when cutting with its single-point tool. On any of these machines such a grinder will help out on many kinds of work.

One great objection to using such devices on the lathe, milling machine, or shaper is that the ways of the machine must be protected from the grit off the wheel and from the chips that the wheel cuts from the work. For grinding wheels do cut actual chips when the right wheel is used and when the speed and feed are as they should be. Covers should be provided for the ways of whatever machine the grinder is being used on, and the machine should be carefully wiped before it is used for its regular purpose on the next job.

Grinding attachments of this type are being used

to grind threads on work in the lathe as well as to finish plain cylindrical surfaces. Although not so fast as regular thread grinders, they make possible the production of ground threads where they are specified without the necessity of having an expensive thread grinder in the shop. Although it is seldom that such a requirement is likely to occur, it is well to remember that the work can be done when necessary if you have a good grinder of this kind.

The workbench should of course be provided with good vises, the size and type depending on the work to be done. For ordinary jobs the vise with a swiveling base is usually very convenient as the work can be swung into any advantageous position. For heavy chipping work a solid-base vise is usually advisable as the blows of a heavy hammer on a chisel impose serious stresses on the pin which prevent the vise from turning when in use. There are many kinds of quick-acting vises, but for most work the old type of screw vise will be satisfactory, and the first cost is much less.

Where portable vises are used to hold work on the tables of machines for drilling or milling, some of the newer types, which have quick-acting jaws and which hold the work away from the bottom of the vise, should be considered. They save considerable time and have advantages over the older types.

It is well to provide "soft" or protecting jaws for bench vises when they are used to hold finished or partly finished work. They save marring the work from the vise jaws, particularly when much pres-

sure has to be applied. These soft jaws are made from brass, lead, copper, or fiber, depending on the kind of work to be held. Brass is seldom used except for comparatively rough-finished surfaces, lead being considered most desirable in most cases. Fiber is also liked for some kinds of work. Lead jaws are made by pouring melted lead into molds made to the proper shape. It is not necessary to have the mold curved to suit the top of the vise jaw as the soft or false jaw can be easily bent to shape when the jaws are clamped in the vise before using.

Hammers should be provided in several weights to suit the different types of work. Both ball- and straight-peen hammers will be found useful at times. Cross-peen hammers are seldom needed. The weights should be carefully considered. Chipping requires a heavier hammer than does riveting. In chipping you want to drive the chisel into the work; in riveting you only want to head or peen over the end of the rivet or other part and do not want the blow to distort the metal to a great depth.

If much hammer work is to be done, the pneumatic or air hammer is very useful. Here again, the weight or power of the hammer to be selected depends on whether it is for chipping or riveting. The portable electric drill is also very useful in any shop for a wide variety of work. In most cases drills that will handle up to ¼-in. drills may be enough, but it is often convenient to be able to drill up to ⅜ in. in this way. They are particularly useful when holes must be drilled in pieces that are too large or too awkward to handle under

the usual drilling machine. Portable drills come in very handy when machines are being erected and when holes have to be drilled after the parts are machined in other ways.

Many shops use a portable drill as a bench drill by holding it vertically, in a suitable frame, over a plate that acts as a table. Where neither the portable nor the bench drill is in use a large portion of the time, this makes a very satisfactory method. The clamp for holding the drill in position can be made to work very easily so that it takes but a moment to remove the drill from its stand and use it as a portable in any part of the shop. It may be well to consider this possible combination before buying a bench drill in the first lot of machine equipment. As the shop grows, both the bench drill and the portable will be wanted.

In this connection it is well to remember the uses made of many small, low-priced drilling machines during the war. Two or more of these drill heads were combined to form a special multiple or a gang drilling machine for certain jobs that required a number of holes. It would not pay to do this in ordinary jobbing work, but occasionally a contract comes along with a sufficient number of pieces to warrant building up such a temporary machine.

Even on jobbing work there are many jobs with two or more holes of different sizes where it would be convenient to have a gang drill with two or more spindles. This can be arranged by combining portable drills in suitable stands, as suggested for replacing a bench drill, having as many clamps for

portable drills as the job requires. Or the heads of the low-cost drilling machines can be combined in the same way. In fact, you will find that it pays to have several small drilling machines scattered around the shop. For, as most work requires a number of holes to be drilled, it saves time to have a drilling machine at various parts of the shop so as to be near other machines on which work is being done. This also avoids delay caused by having the sole drilling machine tied up on another job. Each shop owner must judge for himself how much he can invest in spare machines of this kind. He may be surprised to check up on time lost in that way and see how far the loss would go toward buying a second machine.

Some suggestions as to shop equipment follow.

SUGGESTED EQUIPMENT FOR LIGHT WORK

Drilling Machines: Bench—1 high-speed (10,000 to 20,000 r.p.m.) for drills up to 1/8 or 3/16 in. One slower speed for drills up to 1/4 or 3/8 in.
Floor machine—capacity up to 1- or 1 1/2-in. holes.
Portable motor drive—to carry 1/4-in. drills.

Lathes: Engine—8- to 12-in. swing. If two lathes, one 8 and one 16 in. One should have taper attachment. Motor-driven tool post grinder (or tool block grinder) to be used on lathe, shaper, or milling machine.

Milling Machine: No. 1 or No. 2 universal, if possible, on account of variety of work it can handle, such as emergency gear cutting.
A Van Norman type machine with universal head

is very useful. A bench-type miller is good for small work.

Shaper: An 18- or 24-in.-stroke machine will handle a wide variety of work.

Grinding Stand: For sharpening lathe and shaper tools. For grinding milling cutters some sort of improvised or regular cutter grinder must be used to secure uniform grinding of cutter teeth.

Benches: Preferably with steel legs and good wooden top. For tool work, a top covered with battleship linoleum is excellent.

Vises: At least one vise should have a swivel base. For heavy, rough work with hammer and chisels, a solid base is better. Provide "soft" jaws for holding finished work. These can be lead or sometimes fiber.

Files: Have a good variety of files to suit various work. They should be kept in racks and not thrown into a drawer. They should be kept free from chips. Chalk rubbed into the teeth will frequently prevent clogging of teeth. Clogged teeth scratch the work.

Hammers: Have several weights of hammers with both ball and straight peen. Cross-peen hammers are seldom required. Have "soft" hammers with brass, lead, or rawhide faces for finished work. Lead or rawhide is better than brass for most finished work. Hammers with split heads allow faces to be replaced readily.

Oxyacetylene Torches: For cutting and welding. Have suitable nozzles for different work. As necessary as machines in the modern shop.

Calipers: Firm-joint calipers are still useful in measuring raw stock and some kinds of work. Micrometers of several sizes are also necessary. Verniers are not used widely. A small set of standard gage blocks is good for checking micrometers and in laying out work.

SUGGESTED MACHINES FOR HEAVY WORK

Drills: Heavy floor machines to take 2½- to 3-in. drills. Radials with 5- to 6-ft. arms.

Boring Mill: Vertical—if only one, the larger the better. Railroad work may need up to 8 ft. for large tires. For other large work, machines where the housings can be moved back to increase the swing are useful.

Horizontal—machines should have spindles of from 3 to 4 in. and rotary tables.

Lathes: 24- to 60-in. swing. Swing of lathes can be increased by use of raising blocks under head- and tailstocks. Gap lathes are also useful.

Milling Machines: Heavy bed types with either vertical or horizontal spindles.

Planers: Heavy, open-side types as they can handle a much wider variety of work than the double housing type.

Slotters: Heavy-duty, crank- or hydraulic-driven, for locomotive frame or similar work. Some kinds of work can be done on either slotter or vertical miller.

Grinders: Good-sized cylindrical grinders for piston rods and crankpins, and similar work.

A large planetary grinder for refinishing air-brake

and other cylinders, the ends of connecting rods, and a large variety of other work.

Rolls: For bending plates on various repair work.

Welding and Cutting Equipment: Should include both oxyacetylene and arc machines.

Small Tools for the Small Shop.—With one's mind centered on the larger problems of equipping a new shop, no matter how small, it is easy to overlook some of the smaller items that go to make up the complete equipment. It is easy to forget such small items as center punches, scribers, and perhaps a few small square reamers with which to enlarge holes a little in thin materials. Sometimes the tang of a file can be ground so as to present sharp edges and will answer nicely if it is hard enough. Or a worn-out small square file can be ground smooth on the point and serve very well as a reamer.

Center punches are common bench tools. The points should be kept sharp, generally at an angle of about 60 deg. It is well to taper the punch so as to have the larger diameter of the coned end small enough to see just where the point is when laying out work. It is also convenient to have a few small round punches with flat ends to use in driving pins out of shafts. They are sometimes handy in getting out stubborn cotter pins as well.

Scribers are simply sharp, hardened ends of a rod. A square portion in the center is easier to hold than one that is all round. They are used in scratching fine lines on sheet metal or on other work, as a guide in filing or machining.

Small cold or cape chisels are also very necessary at times in getting into small places and removing small amounts of metal that are hard to get at. Then, too, a drawing chisel with a round point and the end ground at an angle, as shown in Fig. 1, is almost necessary in some drilling work, for, after center-punching a point to be drilled, the drill will

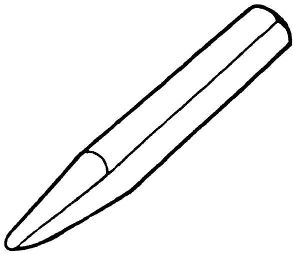


FIG. 1.—Round-pointed or "drawing" chisel for use when drilling.

sometimes start to *run* off to one side. This can be corrected by using a drawing chisel to chip a small groove in the side of the cavity made by the point of the drill, so that the drill will be drawn back where it belongs. A little care will correct the error.

Tools for Measuring.—An important part of the equipment of any shop is the measuring instruments of various kinds for checking dimensions. Although almost every machinist now has his micrometer, this is seldom one of over 2-in. capacity, and there are many cases where a larger one is necessary. So the shop, even the small one, must regard some measuring devices as part of the regular equipment, and a few micrometers, probably measuring up to 4 in. at least, must be considered.

A small set of measuring blocks is also an asset, especially if accurate work is to be done. The fact that the shop has a set of standard blocks adds to its prestige and helps convince customers that accurate work can be done. These blocks are very useful in checking the micrometers, especially those which belong to the workmen. Many overlook the fact that even micrometers wear from use, and there is nothing more misleading than to depend on a micrometer that is not accurate. Some workers are so wedded to their old micrometers that they seem to think the gage blocks must be wrong when they do not agree.

There are still many uses for the old firm-joint calipers, for both inside and outside work. They are particularly useful in measuring rough stock, such as steel bars or flats, and in comparing sizes where extreme accuracy is not necessary. They are inexpensive, are very convenient to use in many cases, and save wear on micrometers.

Although some men like to use the vernier type of caliper for accurate work, most prefer the micrometer on almost all kinds of work. Many height gages use the vernier, and the men should know how to read them accurately and quickly. For general shop use the micrometer is preferred by nearly all workmen.

If the small shop is likely to handle the making of tools or other articles that require the laying out of holes with great accuracy, such as in punch and die work or for drilling jigs, provision must be made for laying out angles. This can usually be done

best by the use of the sine bar or some modification of it. Devices known as "sine plates" are also now available which help in work of this kind. The use of these will be shown later. At least one man in a shop should make a study of these tools, as they are great timesavers when really accurate work is needed. By understanding the use of such tools as these, the small shopman is in a position to undertake the better class of work and of course to charge more for it. On many kinds of work we pay for the "know-how" as well as for the actual time spent on the job.

Many small shops do nothing but repair and overhaul such household devices as carpet sweepers and lawn mowers and perhaps do a little repair work on automobiles and trucks. For this work only a small part of the machine and tool equipment suggested may be necessary. If a shop is expected to handle work of more complicated character, such as printing presses and textile machinery, or even repair machine tools for other shops, all the equipment suggested will be very useful, if not absolutely necessary.

Financial limitations may make it necessary to start with only the equipment necessary for the small and more simple repairs suggested at first. But most mechanics want to look ahead to handling a wider variety and a better class of work than that. For this reason the more expensive equipment is suggested. It is far better to start with a minimum of outlay and handle only the simplest repairs at first than to invest more than can be afforded until the income warrants an expansion. A slow growth

is far better than a big splurge and failure from lack of funds.

Care of Machinery.—As long as your machines are good enough to use, they are worth taking care of. Some old-time shopmen used to think that machine tools had to rest, the same as the men who ran them. Unless parts of the machine get overheated from steady running, there is no need to worry about their getting tired.

But they should be kept clean in all wearing parts even if you are too busy to clean all the painted surfaces. Dirt and chips left on the ways of any machine soon affect its accuracy. Ways of machines not in use should be kept covered, especially if grinding is being done in that part of the shop. Small particles of abrasives fly through the air and settle on ways and flat surfaces especially.

Too many machinists get in the habit of laying wrenches and tools on the lathe bed or on the carriage. Although this may do little harm on the carriage, except to make dents or nicks, these nicks do not improve the accuracy of the ways. It is much better to provide a tool board to go over the ways, or set a shelf or rack in a convenient location.

A stiff brush should be kept in a handy place near each machine or near a small group of machines. Men soon get the habit of brushing chips from the ways and from the work. This is particularly necessary where work is being held in a vise, as on a shaper or milling machine. Unless the chips are brushed out of the vise each time a piece of work is put in place, it is impossible to get accurate work.

It is also a good plan to set a definite time to clean machines. Some shops take the last half hour of the work week. Others think it better to take a little time each day. In some large shops the machines are cleaned by a special group of men after the work is done. But looking after the machine a man runs

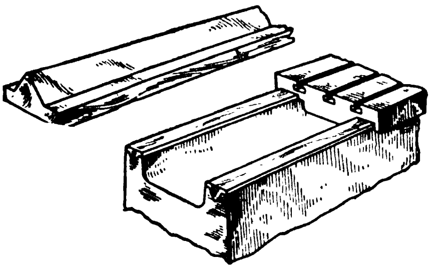


Fig. 2.—Wooden strips for protecting planer ways when not in use.

gives him more pride in it, especially in the small shop.

One excellent way to keep machines in good condition is to cover the ways when they are not in use. Many small shop planers stand idle for a considerable part of the time and collect dust in the ways. These ways should be covered when they are to remain idle, and this can easily be done by making lightweight plyboard guards to lay over them from the end of the table to the end of the bed. These can be in the form of a shallow trough with the edges turned down to keep them from being pushed off sideways, which is perhaps the simplest form of protection unless you use some sort of fabric on the tarpaulin order.

One small shop uses the method shown in Fig. 2,

which consists of wooden strips shaped like the ways on the planer table and fits into the ways on the planer bed. These are simply laid into the ways when the planer is to be laid up for a few days. Either method is satisfactory. Similar devices can also be used on some lathe beds and on milling ma-

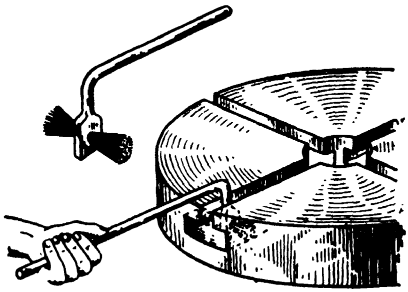


FIG. 3.—Wire brush for cleaning face-plate slots.

chines. The kind of guard is not important, the main thing is to be sure that the ways are protected.

Cleaning T Slots.—T slots have a way of catching and holding chips that interfere with getting T-head bolts in place when you need them. Nor are they easily cleaned out with the ordinary brush or scraper. A piece of old wire rope fastened in a handle, and with the ends of the rope frayed out to form a brush, makes an excellent cleaner for such slots. The way this looks and also the way it works are seen in Fig. 3. The small piece of wire rope can be held by friction from being a tight fit in the hole, or the end of the rod holding it can be split and the rope clamped in the handle. This makes it a little easier to

change brushes when the old one gets out of shape or loses its effectiveness.

Keeping Electric Tools on the Job.—*As practically every shop, large or small, has one or more electrically driven hand tools, it is important that* they shall be in working order when wanted. There is nothing more exasperating than to pick up a tool for a rush job and find that it isn't in working order.

One of the best-known makers of tools of this kind has the following suggestions regarding all tools of this kind:

Electric wiring is an important item in shops using electric portable tools of any kind. The wires should be large enough to carry sufficient current for the tool in addition to the lamps and other appliances on the circuit. Wappat, Inc., makers of portable electric tools, stress this point and advise the use of larger sizes of tension cables as their length increases. They suggest the following wire sizes for drills of different diameters:

Length of cable, ft.	Size of drill, in.			
	1/4	3/8	1/2	3/4
50	No. 18	No. 16	No. 14	No. 14
125	16	14	12	10
250	14	10	10	8

Small cables, or small wires in the shop circuit, reduce the voltage available at the tool. This overloads the motor and causes it to overheat, sometimes burning it out.

Electric tools should not be run idle as they overspeed, which is hard on both the carbon brushes and the lubrication. Motor bearings should be lubricated at regular

intervals as directed by the maker. Brushes should be carefully watched and replaced when worn to half length. When not over $\frac{3}{8}$ in. long, they should generally be replaced. The commutator should be round and smooth. Use a clean cloth or very fine sandpaper when the commutator is dirty. Never use emery cloth or paper.

It is suggested that the gear case of electric drills should be cleaned and refilled after each 500 hr. of service. For continuous service at 8 hr. a day, this means every 3 months. In the average shop, a cleaning and greasing every 4 months would probably be ample—and in many cases a 6 months' cleaning date would be all right. But a record should be kept so that the infrequent cleanings are not neglected.

Some electric tools are equipped with three wires, one of which is grounded in the tool. With this wire connected to a ground, the operator is protected from shock should any ground occur in the motor.

Overload, dirt, and insufficient or improper lubrication are the three causes of trouble given by manufacturers of electric portable tools. The failure to keep a motor clean with an air jet is responsible for much of the overheating troubles. Universal motors, which operate on either a-c or d-c current, are subject to higher operating temperature than plain motors. This increases the need for care in keeping the ventilating passages open. As they heat much more in summer than in winter, care should be taken to use a lubricant that will stand the summer working temperature.

Electric drills and other tools should be cleaned at fairly regular intervals. Gasoline or naphtha is used for cutting grease and oil. The motor should not be started until the vapor from the cleaning fluid used has entirely evaporated.

CHAPTER III

SMALL SHOP LAYOUT

All shops should be laid out so as to avoid unnecessary movement of material as far as possible. The heavier the material used, the more important it is to keep its movement at a minimum. The arrangement of machines is usually of less importance as distances between them are short and no one can tell in advance what the sequence of operations will be. Unless the small shop is manufacturing a regular product, which seldom happens, it is impossible to lay out any resemblance to a production line.

Hacksaws and cutting-off machines, if any, should be near the racks where the raw stock is stored as operations on these always come first. Beyond this it is hard to say in advance whether drilling or turning will be the first operation. If it is bar work, the pieces must be centered, which puts the drilling machine next to the raw stock in most cases. If the work is to be done in the chuck, centering will not be necessary. If there are several drill presses, it may be well to scatter them through the shop instead of grouping them into a drilling department. Many good-sized shops find it convenient to have a drill press near various machines as it often happens that drilling has to be done between machining operations.

It is important to arrange machine tools so that there is plenty of space not only for men to work but also for material to be handled in and out of the machines. For this reason machines are often placed at an angle to the shop walls but parallel to each other. This is important in the case of screw machines so that the long bars through the hollow spindles will clear the next machine without spacing the machines too far apart.

If the machines are motor-drive, as is usually the case at present, it is not a great job to rearrange them as experience shows to be best. This was a very different proposition in the days of long line shafts and countershafts on the ceiling over each machine. This made it necessary to move pulleys on the line shaft, to rearrange countershafts, and otherwise to mess up the shop. The individual motor is also a money saver when you have to use one or two machines at night on a rush job and when nothing else is running except the machines you need. Although individual motors cost more both in initial investment and in operation than group drives, the extra convenience is worth all it costs, and more.

The larger the shop, the more important it is to keep work movement as short as possible. It not only requires labor to move work from department to department, but it also delays the work more than might be imagined. Someone has to watch the movement of stock in process and see that it is moved to the next operation with as little delay as possible. It also means considerable paper work in

the shape of "move tickets" to show the move man where the tote boxes or platforms go. He should bring back a coupon or something to show that they have been delivered to the proper place. All this costs money and adds to the overhead expense. The more work is delayed, the longer it takes to get your money for the work. This decreases the rapidity of "turnover," which means the rapidity with which you get back the money you have put into material and labor.

Another important part of running machines is the planning of the work to be done by each machine. This requires experience and good judgment, and perfection is not to be expected. Estimates on the time needed for any job must be based on average conditions both as to the materials and tools used as well as to the men who are to do the work. Tables of cutting speeds and feeds for different operations help a lot, and several will be given later. But these must be considered as guides only and not as hard and fast rules to be followed implicitly. The greatest variable is the human element, the man doing the work, whether you do it or one of your men.

Weather, sickness, or other disturbances at home, and your own physical feelings all affect the speed with which you will grasp the problems of the task to be done. The time taken to handle work in and out of a machine, the setting of the tools, and the general alertness on the job depend on many things besides your knowledge of the work. This also holds true for everyone else in the shop and must be allowed for in estimating. Then, too, drills will

break, sometimes halfway in the work, and have to be taken out as best they can. Tools will get dull, and at infrequent intervals the power may go off. But you can congratulate yourself that this happens far less frequently than in the days of the line shaft, countershaft, and belt drive.

There are still many shops using belt-driven machines and doing good work. From the point of view of power cost alone they may have an advantage but they would lose less time with motor drives. For one thing, the convenience of being able to run only one or two machines is worth all it costs over the belts. Then, too, a motor large enough to run a group of machines is not efficient when only a small part of them are in use. Belts gave excellent service in their day, but they required a lot of attention and gave out at most inopportune times. This required stopping the whole shop at times and having a good mechanic stop and lace the belts, or possibly patch a piece into it if the ends had pulled out.

The shop that can keep its machines running at any time of day or night as necessary, and operated by a mechanic who knows how to handle unusual repair jobs, can build itself a reputation that will draw customers from miles around.

So much depends on the size and shape of the room or rooms to be used for the shop that it is difficult to give any very definite plans for the shop layout. Assuming that they are square-cornered rooms, the three plans in Figs. 4 to 6 may be found useful as they are taken from actual shops. The first two are considerably smaller than the third

and have much less equipment. All of them should suggest possible machine layouts that will fit into a number of rooms to be used for the small shop. If, as sometimes happens, the space available is of an L shape, these layouts can be modified to suit.

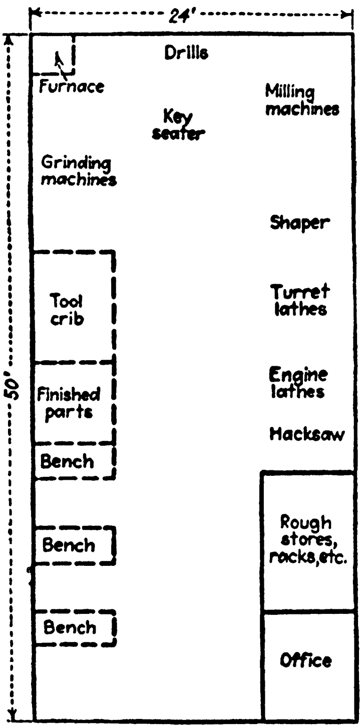


FIG. 4.—Suggested layout for a small shop.

One of the first considerations is the way in which the raw material is to be brought into the shop and the finished work taken away. With shops on the ground floor it is well to have a loading platform either at the back or on one side. If the shop is in a city where loft buildings are used, it is necessary to be sure that the elevator service can be depended upon, and the end of the shop nearest the elevator can be used for storing rough stock and also for shipping the finished jobs.

If the work is rather small, it may be best to store it on benches rather than on the floor and so save unnecessary stooping when it is being handled.

Whether you do the work yourself or it is done by others, every effort that can be saved adds to the efficiency of a shop. This applies just as much to the owner as to any of the men. Saving steps and all unnecessary exertion leaves more energy for useful work.

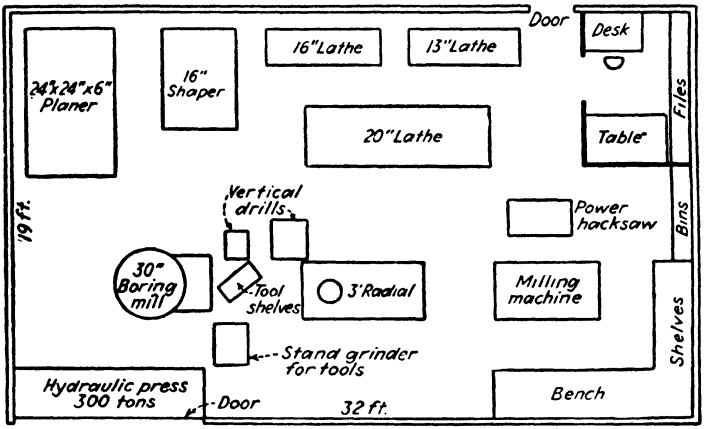


FIG. 5.—A compact layout for a shop that handled a large variety of work.

All three of the layouts shown contain suggestions that can be applied to many other shops. They all have different machine equipment, which of itself affects the way in which the machines are arranged in a shop. All of them have the office in one corner, which is a favorite place as it reduces the opportunity for noise to disturb conversations with customers, when partitions are not used.

In most cases the exact layout of the machine equipment is not particularly important so far as handling the work is concerned because one never

knows what the sequence of operations will be on the next job. Some work may require the drilling of a few holes to serve as locating points for future operations. Other jobs may make it best to machine some flat surface before any holes are drilled. With

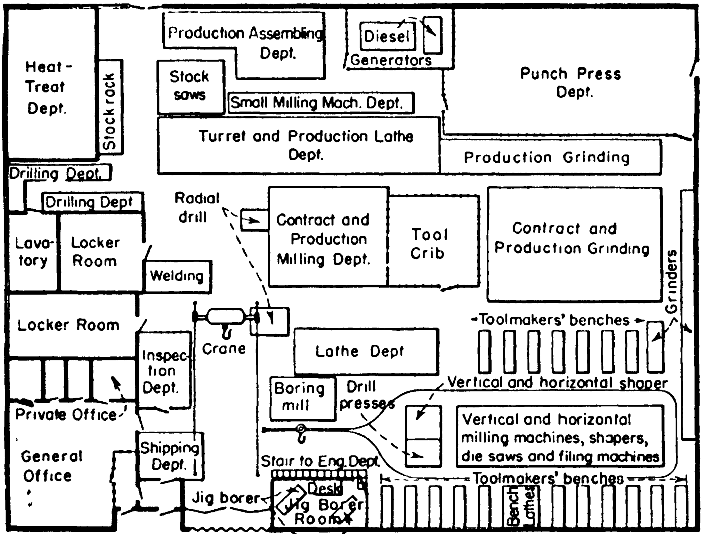


FIG. 6.—The shop was laid out for four kinds of work: tool and die, production, contract, and special low-cost punch-press work. It provides facilities for a large variety of work.

the short distances between machines in a small shop the handling of work between them is seldom a very important item.

Of greater importance in most cases is the location of the windows for lighting both the machines and the workbenches, and allowing sufficient room around each machine to handle the work it will be called on to do. If a shop is on the ground floor,

the weight of machines does not generally interfere with locating them as seems best. But where the shop is on an upper floor, their location may depend largely on the type of building in which the shop is located. Nearly all modern loft buildings made to house small industries are built sufficiently strong so that the machines likely to be used can be located at any point most convenient from the shop point of view. The floor-load capacity is always given and, if necessary, the heavier machines can be located near the walls or supporting columns.

Should the shop be above the first floor, in a building not designed for this purpose, great care should be exercised in locating machines. This is from the point of view of safety both to the building and also to the work that can be secured from the machines. Unless machines have a substantial foundation, it is not possible to secure the results from them that can be expected where vibration is not present. Lack of a good foundation may cut the work of a machine as much as 50 per cent in some cases.

It will be noted that in two of the floor plans the benches are placed at right angles to the wall or the windows. This is considered the better layout by many both because the men do not face the light and also because work can be done on both sides of the bench. In some cases it is better to have the light come from one side, while in others the opposite may be true. This may make it easier for men who are decidedly right- or left-handed, bringing the light on either side. Lighting for the toolmakers' benches toward the center of the shop, in Fig. 6, must be artificial in most cases, as they are too far

from the windows to depend on daylight. In many cases artificial light will be found more satisfactory as it does not depend on the time of day or the weather, but can be kept constant. The kind of light and the amount to be supplied should be determined by those who specialize in this factor of shop equipment. It does not pay to try to save money by skimping on light. It does pay to make it a habit to turn lights off when they are not needed.

The shop shown in Fig. 6 is much more complete than is likely to be set up by any beginner, but it gives ideas for expansion. Some portions of it can be selected as a plan to be followed. The equipment mentioned earlier did not include heat-treating furnaces, as shown here. It might be that these would be more useful in some small shops than some of the machine tools suggested. In fact, the selection of equipment is likely to vary widely according to the line of work that the owner plans to follow.

The amount of floor space required for a shop depends largely on the kind of work to be done. A small shop cannot afford to waste any space, neither can it afford to handicap the men by not providing enough space for them to work efficiently. One shop planner uses the following allowance per man for work of different kinds:

Assembly work	100 sq. ft.
Sheet metal	150 sq. ft.
Heat-treat and welding	200 sq. ft.
Machine work	125 sq. ft.
Forge and foundry	180 sq. ft.
Painting	250 sq. ft.

Bins and Storage Space.—Provision should be made for bins and storage space. Both Figs. 4 and 5 have provision for storage but it is not emphasized as it should be. It is particularly important to have places for keeping small supplies such as machine screws, small bolts and nuts, washers, cotter pins, and the like, where they can be found easily and not overlooked when you want them in a hurry. Although these do not run into very much money by themselves, it should be possible to avoid buying a new supply when there are already some in the shop. The delay caused by going out to buy more is often more expensive than the cost of the articles themselves.

Trying to keep a running inventory of such supplies means a lot of paper work and takes time. Even if attempted, it is usually neglected when in a rush, and the records become useless. It is better to have such supplies where they can be seen at a glance. One good way is to use glass jars with screw tops for small screws and similar parts. These show at a glance what sizes are in stock and approximately how many of each. A method of doing this is shown in the next chapter.

Some such arrangement is much more satisfactory than trying to keep such material in bins, or even in the packages in which they are bought. The packages must be taken out to see the label, and if in bins, they are not always easy to see. Needless to say, it is not good practice to keep them on benches, on the floor, or in drawers, unless they are in glass containers so as to be easily seen when the drawer is opened.

CHAPTER IV

SHOP FURNITURE

The wise selection of shop furniture, such as benches and lockers, is important. Although perhaps not so important as the machine equipment, poor benches can delay work and also cause dissatisfaction among the workers.

Unless you can save enough money to make it worth while by building your own benches—which is doubtful—it is better to buy standard equipment, made by those who specialize in such work. You are very apt to have more satisfaction from those of standard make, preferably those made of metal. Wooden tops are generally better for average work. If they are to be used for heavy work, the benches and vises should be fastened securely to prevent movement when a large wrench is used or when heavy chipping is being done. False or soft jaws should be provided for holding finished work.

Both for the assembling and other handling of small work, it is well to have the bench top covered with battleship linoleum or some board like masonite. It is also advisable to have some slightly raised edges on the bench to prevent small parts from rolling off on the floor. Much time can be lost in hunting for small parts, and there is also the possibility of damage or loss, which might easily cause expensive

delays. In dismantling small mechanisms it is usually advisable to put the parts in small, shallow dishes, both for protection against damage and to avoid the likelihood of loss.

Convenient racks for the safe storage of such materials as steel rods and bars, metal sheets of various kinds, bolts, nuts, and washers, cotter or other pins, and similar supplies will also save time and money. It is a great satisfaction to be able to put your hands on parts that you need without wasting time in hunting through bins, drawers, or boxes. You are also able to keep tabs on your supply of these small but very important items when you are in a particular hurry to finish a job. Suggestions as to keeping these items will be given later.

Although clothes lockers were an unheard-of luxury in old-time shops and workers hung their clothes wherever they could, they are almost a necessity at present. Even if you do all the work yourself, it pays to have a place for your street clothes out of the dirt and dust of any shop. And when you begin to hire others to help you, they are more necessary. They need not be fancy in any way, but they should be large enough and tall enough for an overcoat as well as for other clothes, and a hat and shoes.

Much of the work of a small shop is likely to be handwork, such as taking small machines apart, fitting new pieces, and reassembling. Then, too, no matter how few tools you have, it pays to have them handy when you want them and in good condition.

Files should be kept in racks on, or behind, the workbenches, where they will not be in contact with each other or with metal of any kind. Nothing ruins files quicker than to throw them into a drawer with other files or with other tools, nor do they improve the tools that they touch. They are cutting tools and should be cared for properly.

Drills, reamers, and taps should be kept in separate compartments with nothing harder than wood in contact with them, especially at the cutting edge. Drill holders, which keep each drill in a separate hole and show its size, are very convenient and save drills. They also help in selecting the right drill without delay. Counterbores and other tools should also be well protected.

Hammers should have good handles and the heads so fastened on that they will not fly off in use. Flying hammer heads not only are dangerous to people but can also cause a lot of material damage. Two methods of keeping hammer heads where they belong are shown later. Pliers and wrenches should be well cared for and kept in their proper places, not left lying around on benches or machines.

The time wasted in hunting for pliers, wrenches, and other tools is a distinct dollar-and-cents loss and delays the delivery of work. Prompt delivery of work helps to make and keep steady customers.

Utilizing, Saving, and Storing Materials.—One of the problems, especially of the small shop, is to get full value out of the material that is bought. Machining away more material than necessary not only costs money but also wastes our natural re-

sources to some extent. On the other hand it is sometimes more economical to use a bar larger than necessary for the job, if you have it on hand, than to wait for the proper size. Ordering material, waiting for it to be delivered, and handling it count up to more cost than many seem to realize.

Benjamin Melnitsky, formerly storeroom keeper at the Waterbury Tool Co., division of Vickers, Inc., had some very good suggestions along this line in the *American Machinist* of Mar. 14, 1946. He said:

Short ends of bar stock are often relegated to the scrap pile and accepted as an inevitable materials cost. If they are saved without provision for their use, subsequent recording and storage costs may cancel any material savings and economy. Constructive control of short ends indicates that

1. Short ends should be eliminated wherever possible;
2. Those which do accumulate should be utilized.

Elimination of short ends of bar stock is the fundamental result of good bar-stock control. Where long parts are to be made and production requirements are known, bar stock may be bought in definite lengths, from which an exact number of parts can be made. If the methods sheet shows that the bars are to be sawed in 17¼-in. lengths before machining, stock should be ordered in lengths such as 7 ft. 3 in., 8 ft. 9 in., 10 ft. 3 in., 11 ft. 9 in., 14 ft. 9 in., 15 ft. 3 in., etc., allowing ⅛ in. for each saw cut. If the same part is to be machined in a bar lathe, 3 in. should be allowed for parting-off and facing each cut. The maximum capacity of this lathe should be used for minimum waste, as the same amount of chucking grip is required for long as for short pieces (see Fig. 7).

If such close estimating is not feasible or if purchasing

bars cut to exact lengths is too costly, bars should be bought in random lengths and cut to length at the saws for each order of long parts. When the number of parts is known, there will be no such shortages as occur when bars are delivered according to footage.

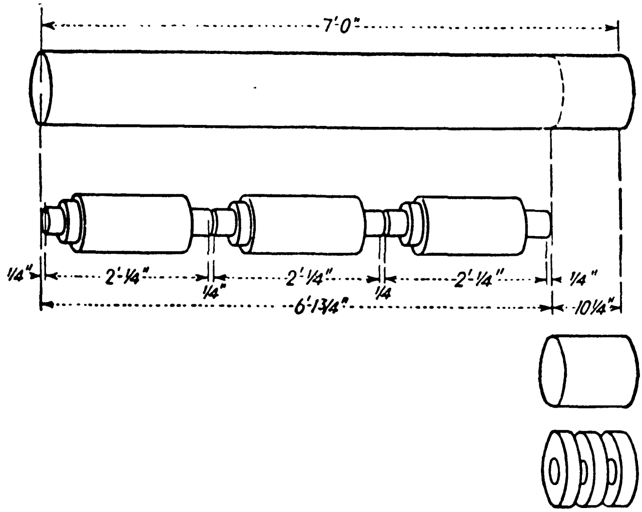


FIG. 7.—How three parts, each 24¼ in. long, may be made from a 7-ft. bar. Spacers were made from the 10¼-in. bar that was left over.

Bars of equal length should be used in multiple-spindle automatic screw machines and lathes. When unequal lengths are used, the machine would have to run with only one spindle feeding stock in order to use the last and longest bar. Cutting to length at the saws eliminates this.

In the ideal storeroom for every size and type of bar stock, all bars in the rack except one should be in full lengths. This is possible if stores personnel use uncut bars only after all partly cut bars are delivered.

No matter how many bars must be cut or how many

saws used, there should never be more than one partly cut bar left after the cutting is finished.

As an example, assume that 1,500 flanges, each 1⅞ in. long, are ordered using 12-ft. bars and allowing ⅛ in. for each saw cut. Twenty bars and a part of a bar will fill the order. However, if six bars are used on each of four saws, 24 2-ft. bars will remain. If six bars are placed on two saws and four bars on the other two saws, all 20 bars will be completely utilized. The first two saws produced 432 flanges each, the second two produced 288 each, and the remaining 60 flanges can be cut from the last bar—leaving only a 2-ft. bar instead of 24 such bars.

Another means of eliminating short ends is to run two jobs through the shop at one time, one job for long parts and the other for short parts, each of the same type and size. What is left over from the long parts is used for the short parts. When sawed-to-length forgings are run through the shop, the butt ends can be used in fabricating small parts.

Handling Short Ends.—At one time, all short ends of bar stock in the steel room of a large New England manufacturer were inventoried and charged off individual card balances. Bars were considered as "scrap" only if within the limitations of the accompanying chart. Thus, charging off short ends was controlled and limited to definite lengths for each size of bar stock.

Following this the short ends were placed in racks so designed that they were ready and accessible.

To prevent further accumulation of short ends in the regular rack, short ends were charged to the job that produced them. If material for a job weighs 75 lb. and the leftover end 15 lb., a total of 90 lb. is charged against the job and the end placed in the scrap rack. Should the length of this end be greater than the length of scrap for the sizes listed on the chart, the material is

replaced in the rack and not charged against the job. Steps are taken to maintain identity of material in the scrap rack, and if it cannot be identified it is discarded.

When scrap is used to fill an order, the requisition is clearly marked so those posting it will know it is filled

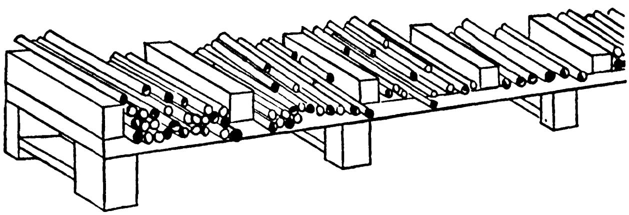


FIG. 8.—This heavy wooden rack stores bars so they are readily accessible.

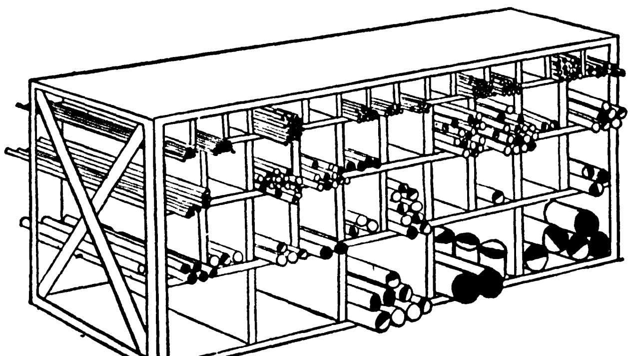


FIG. 9.—Rack designed for short ends of bar stock. They are stored by size and take up little space.

with material already charged off the records. The requisition may be posted on the regular card for size and type of material in such a way that it will be apparent that the material was not taken from the regular stock.

Utilizing Short Ends.—Once the technique for handling such material has been established, all short ends may be

utilized to the maximum degree. Material for tools, jigs, fixtures, stock for test setups, bar-stock maintenance work, and any nonproductive jobs should be taken from the scrap whenever possible. This is important where bar stock is allocated and purchased in accordance with periodic production requirements. Excessive withdrawals of stock for other than production work may seriously distort allocation records and result in shortages for certain parts.

If every order reaching the storeroom is first checked against material in the scrap rack, an amount of scrap may be used for regular production orders. Scrap machined parts should be returned to storeroom, where the machined areas can be sawed off and the clean stock saved. Obsolete parts, canceled parts, discarded tools, obsolete forgings, and anything that has clean stock and can be identified as to type material may be sent to the saws for salvage and storage in the scrap rack. A scrap system, rigidly followed, saves much paper work because material in the scrap rack is charged off the record.

CHARGING OFF SCRAP BAR STOCK

Size of Stock, In. Round, Square, Hexagonal	Minimum Charge-off, Ft.
1	3
1 1/16–2	2 1/2
2 1/16–3	2
3 1/16–3 1/2	1 1/2
3 9/16–4	1
4 1/16 up	1/2

Use same chart for flat stock. Go by smallest dimensions.

Figures 7, 8, and 9 illustrate methods of saving and storing bar stock. Figure 10 shows a compact tool cabinet used in a large railroad shop.

Trays for Small Parts.—Another method of storing small parts is illustrated in Fig. 11. Although it

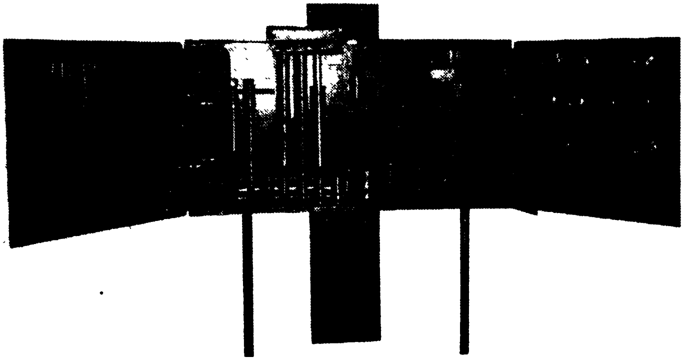


Fig. 10.—Tool and cutter wall cabinet in a railroad shop.

does not show all the contents as freely as the glass jars, some shops find it very convenient for small parts as may be used on the assembly bench, such as machine screws, cotter pins, washers, taper pins, and similar parts. This shows how one shop used rather small, round tin cans, all of one size and with covers attached, for this purpose.

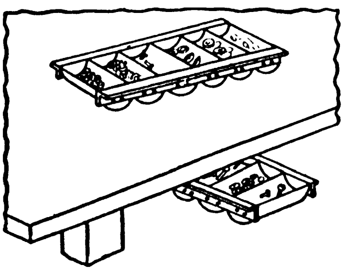


Fig. 11.—Trays made from tin cans.

The cans are split lengthwise and the tops and bottoms fastened to light angle-iron strips to form a tray with several compartments. The fastening can be done by riveting or by welding, as is most convenient. As shown, they are made in nests of

six half cans, which can be slid under a bench or shelf when not in use. Shelves can be quite close together and provide a lot of storage in a small space. In most cases the tray will be used by taking it out of its slide and setting it on the bench as shown.

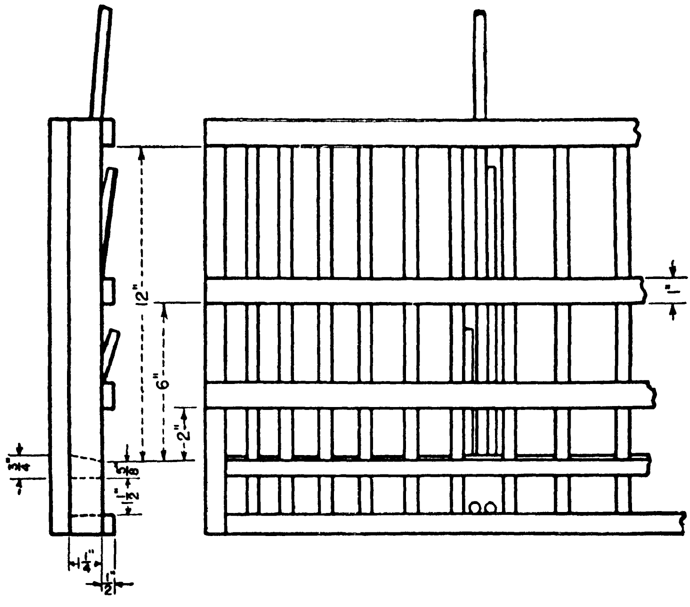


FIG. 12.—Rack for storing bars of various lengths.

Drill rod and similar materials are not easy to store so they can be readily seen and are easily accessible. Unless the short pieces can be found when wanted, it is necessary to cut them from a long rod, and this may mean considerable waste in the course of a year. This problem was responsible for the designing of the storage rack seen in Fig. 12. By storing in this way the short lengths can be put in

front where they are easily seen and can be removed without handling a lot of longer bars.

This is a self-contained rack, having a back and a bottom, which can be moved to any desired location. It is only necessary to anchor it at or near the top to prevent tipping. By putting the upper edges of the crossbars at even inches from the base on which the rods rest, it is easy to estimate the approximate length of the short rods and so save time in picking them out for any special job.

The partitions can be spaced to suit any special conditions of the work that predominate in the shop. Two widely differing sizes can be placed in one bin if necessary as the difference in size makes it easy to pick whichever one is wanted. At the bottom is a row of small compartments for storing very short pieces that are very likely to be lost if dumped into a bin with other material. The side view shows how the upper ends project from the rack so that they can be reached easily.

Long bars are somewhat troublesome in many cases. They can be stored against a wall, arms projecting from the wall being used for supports. These arms are either straight and set at an angle to let the work roll against the wall, or curved to prevent their rolling out of the rack. Whatever the arms, they should be designed and built to stand the heaviest load that can be placed on them, this load being limited by the spacing of the arms. Long bar racks are also made in the form of stands with a central support and placed in the shop be-

tween departments or behind the screw-machine department, in many cases.

Racks of this kind can be used to hold all kinds of short bar stock in addition to drill rod. This, or some similar rack placed near the cutting-off saw, will make a convenient place to store short ends when cutting up a long bar. It will also frequently be possible to find the right piece needed for some special job and save time in hunting over a stock pile, which is too often a junk pile. Many shops waste more time in hunting for a piece of bar or other stock than the stock itself is worth. If a good variety of stock is kept on hand, it is seldom necessary to turn down, or otherwise machine, unnecessary metal from a bar that is too large. On the other hand, it may be more economical to waste a few pounds of metal by machining more metal than necessary in order to save the time necessary to procure a smaller bar from the warehouse. Solving problems of this kind successfully is a test of good management.

Another type of storage is shown in Fig. 13. This was built from No. 20 gage black iron and has 16 compartments for storing ground flat tool stock. The compartments are 18 in. deep and 3 by 4 in. each. These sizes can, of course, be varied to suit. As shown, the rack or stand was made up by riveting but it could just as well be welded. In this case it was fastened to the floor by screws through the feet, but this can often be omitted. It might also be advisable in some cases to use shorter legs and add

a few more rows, or layers, to the bins for holding steel. Although this was made for tool steel, similar racks might be found useful in other parts of the shop. The framework of this stand is made of ⅛- by 1-in. angles, with the lower ends sawed up the center and bent outward to form the feet.

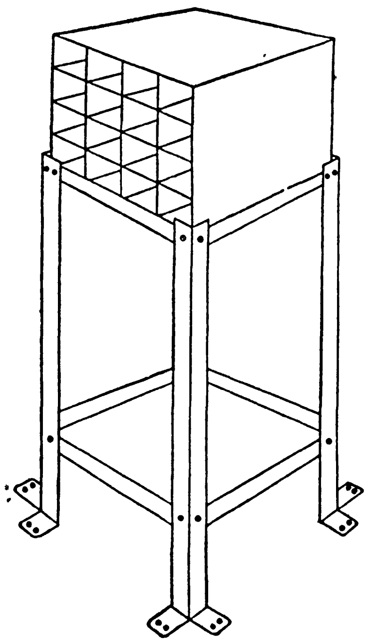


FIG. 13.—Light rack for flat steel stock.

Another somewhat similar idea, but made of wood, is seen in Fig. 14. It is beside the cutting-off hacksaw, which is mounted on a base high enough to bring the stock being cut to a convenient bench height so that the bench can be of help in handling long bars in and out of the hacksaw. When short pieces are left from the longer bars, they are stored in the bins shown. In this way it is very easy to see whether a piece of stock of the right size for a job is available or not.

A different type of storage is seen in Fig. 15. Although this was made for storing punch-press tools beside the experimental press on which they were used, the method is equally useful for other

purposes. Each bin or compartment is closed by a door hinged at the bottom so that it swings down out of the way when opened. In this way the door is not interfering when tools are to be removed or

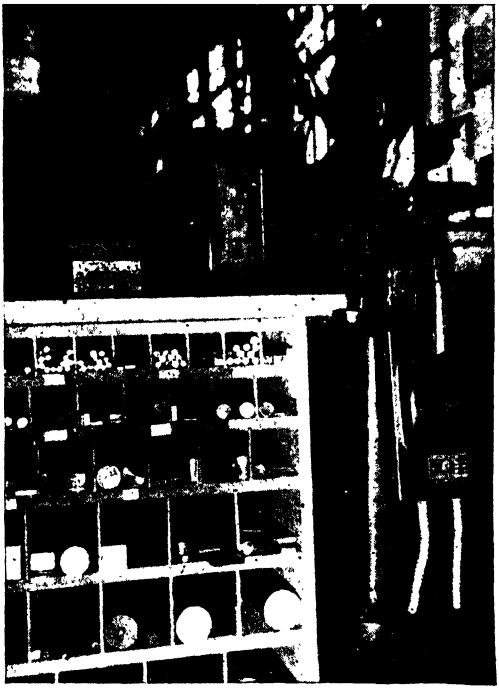


FIG. 14.—Storage bins beside a power hacksaw.

replaced. A similar arrangement would be very handy in storing other kinds of materials, as well as tools of various kinds, away from the dust that accumulates in the best regulated shops.

Vertical Storage Saves Floor Space.—Where floor space is limited, it is well to consider what may be

called "vertical" storage methods. This does not mean indiscriminate piling of one box or rack on

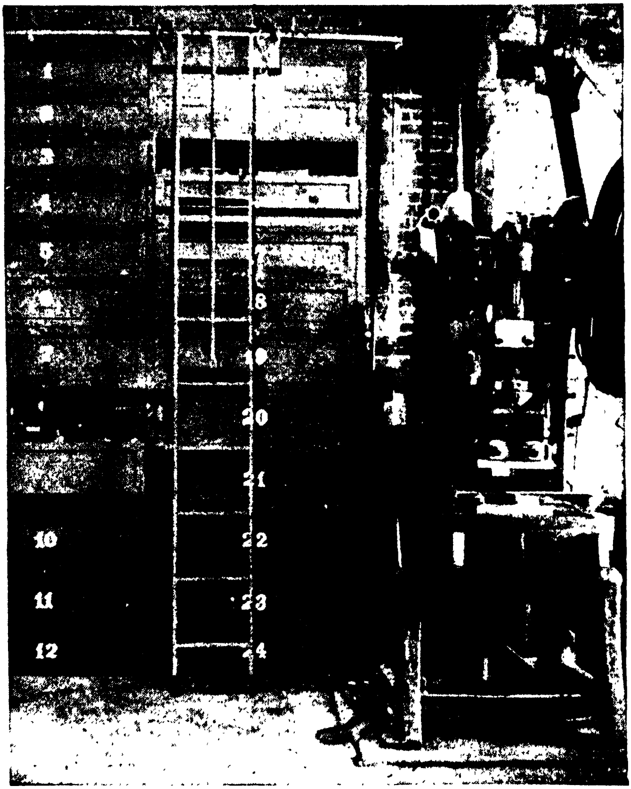


FIG. 15.—Storage for punch-press tools.

top of another as that requires a lot of handling and often delay, because the box wanted is apt to be at the bottom of the pile. The method used by the Lewis-Shepard Co. is claimed to save at least 25 per cent of the floor space needed if this method

was not used. A section of their vertical storage racks is seen in Fig. 16.

By using regular skid bases and hand-operated lift trucks, as well as a power-operated stacking truck, seen at the extreme right in Fig. 16, either

FIG. 16.—Vertical storage saves floor space.

the stack of skids can be handled as a unit or single skids can be stacked as shown. Above the stacks of skids, finished or semifinished parts of the product are stored, either between operations or while awaiting shipment.

All three of these storage plans have proved very successful in three entirely different types of shop. They can, of course, be modified to suit special conditions that may arise in any shop, even though the

type of work may be entirely unlike those mentioned. In some cases it might be better to hinge the doors in Fig. 15 at the top. They are good plans to file away against the time when the small shop will have to expand considerably.

Keeping Screws and Small Parts.—Screws and small parts have a way of disappearing and not being found when needed, especially when they are carefully put away in boxes or small metal cans. To avoid this, many use small glass jars, which have the advantage of letting you see just what is inside without taking the cover off.

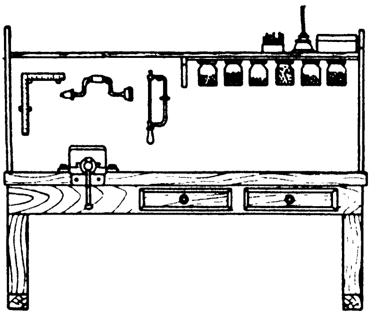


Fig. 17.—The use of glass jars below shelves for storing screws and other small parts.

In using the contents, however, the cover must come off and this means using both hands, one to hold the jar and the other to unscrew the cap. It is much simpler to screw the cap on the underside of a shelf, as shown in Fig. 17. Then the jar can be unscrewed with one hand while the other hand perhaps is holding the piece of work for which the screw or other part is needed.

Further advantages are that the jars are up off the shelf, that they are not likely to be pushed around or off on the floor, and that you have to cover the contents whenever you put them away. As this method does not use shelf

space, you can utilize the undersides of several shelves if necessary and still leave the shelves themselves for other use.

It is not a new idea but it is very convenient.

Blocking Up Work for Machining.—Step blocks and a variety of straps or clamps are necessary in holding work of various kinds to planer tables and on other machines. This is particularly true when the work is of irregular shape, such as castings or forgings. Step blocks are much safer as well as more convenient than dependence on piling up a variety of flat pieces of various kinds. It is much safer also both as to the work itself and as to the men running that machine.

Figures 18 to 23 show a variety of jobs blocked up with a combination of step blocks and other blocking. Figure 23 shows both good and bad ways to use ordinary straps in holding down work. Those at the left are good because in each case the straps are approximately level and the hold-down bolt is as near to the work as possible. Those on the right are bad because the straps are not level and, in one case, the hold-down bolt is not near the work.

Plain blocks, or parallels, are very convenient, and when they are parallel on the sides and also square on the angles, they help in locating work that will be true with the bed of the machine.

V Blocks.—An assortment of V blocks is very handy in locating work on a planer or shaper and sometimes on a milling machine. They can be machined at odd times when there is no other work for the shaper or planer. A very good substitute for

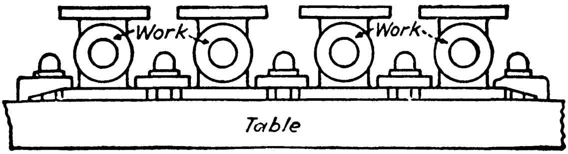


FIG. 18.—Standard clamps used on multiple work.

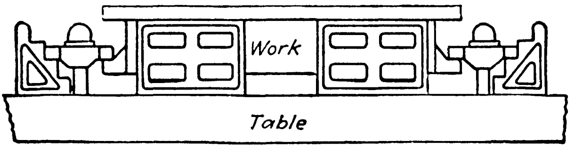


FIG. 19.—Using step blocks and clamps.

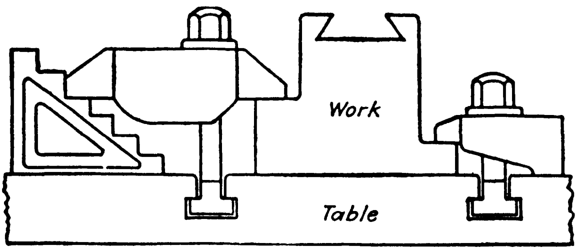


FIG. 20.—Clamping unequal heights.

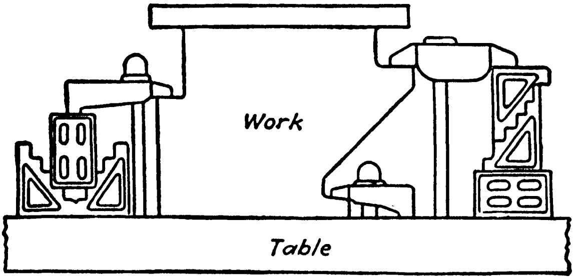


FIG. 21.—An unusual clamping combination.

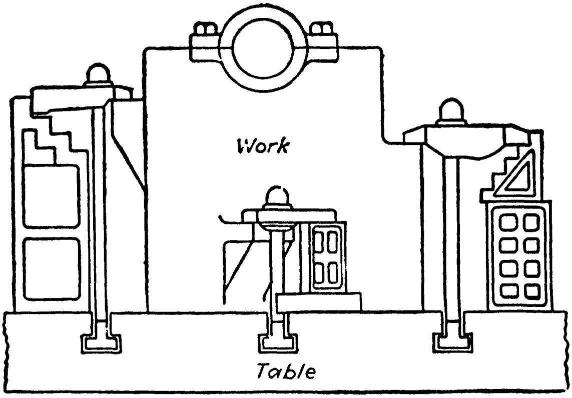


FIG. 22.—Clamping work at three different heights.

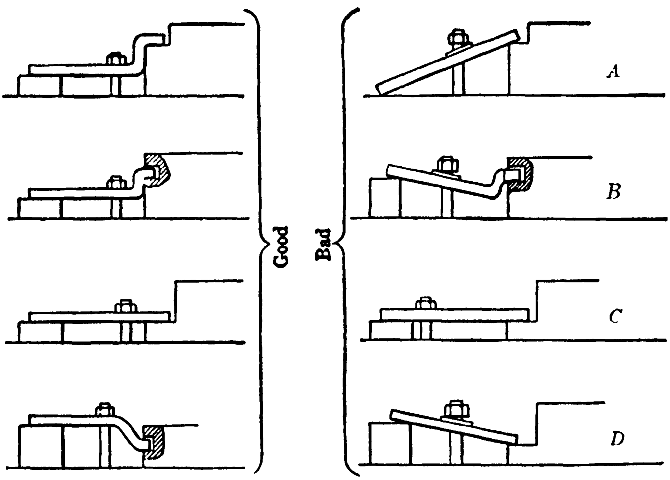


FIG. 23.—Right and wrong ways of using straps.

the regular type of V block can be made by bolting, riveting, or welding two tubes together, as shown in Fig. 24. With tubes of the same diameter and

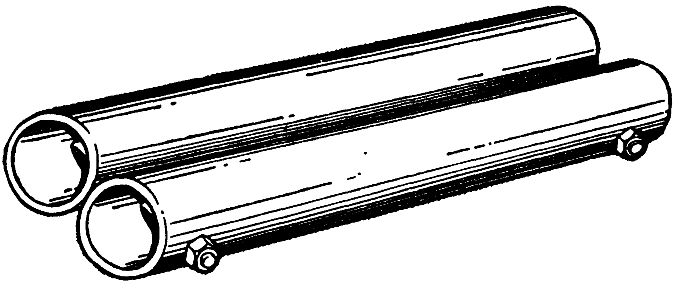


FIG. 24.—Substitute for V block.

with care to have them so fastened that both tubes lie flat on a table or surface plate, these make very good V blocks. They also have the advantage that they can be made without the use of a planer or shaper.

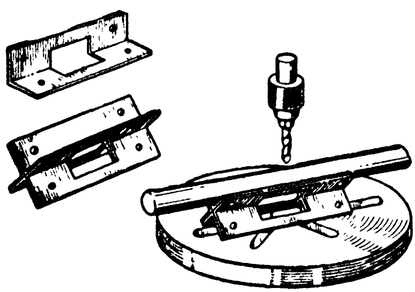


FIG. 25.—V block made of four angles.

Another V block, made of four angles riveted together, is seen in Fig. 25. With the center cut away as shown, a drill can go through the work. This makes this design better than the tubes for drill-press work.

Vises.—Both bench and machine vises are important in all kinds of shopwork. For the bench they should be of heavy design if any chipping is to be done. One vise should have a swiveling base in order to swing into convenient positions for different kinds of work. Heavy chipping should be done on the

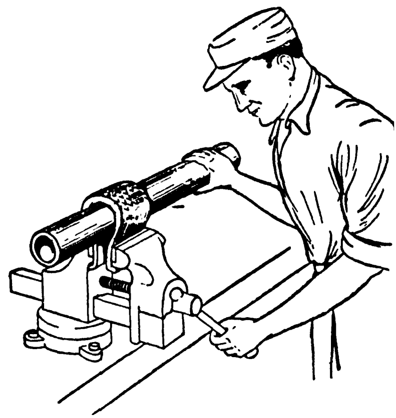


FIG. 26.—Utilizing discarded rubber tire in the shop.

solid-base vise. If there is much small work to be done, it will pay to have a rather small and light vise especially for this work, perhaps of the quick-clamping variety.

Rubber Helps Hold Work in the Vise.—Holding light tubing or other more or less fragile material in a vise without crushing or damaging it in any way is not always easy. Two methods that utilize parts of discarded rubber tires and of a hose are shown in Figs. 26 and 27. The first shows how a piece of a tire casing, or shoe, is used to grip a thin-walled tube without damage of any kind. By uti-

lizing the bead on the tire to draw the tire section close around the tube, considerable friction can be secured. This applies pressure all around the tube and has very little tendency to crush the tube, no matter how thin the wall.

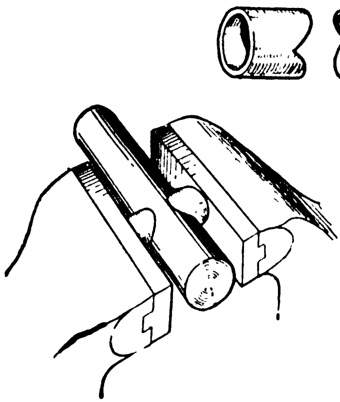


FIG. 27.—Pieces of old hose hold plastic rod safely.

Another method is also seen in Fig. 27. This was used to hold a plastic rod that was so brittle as to be easily crushed if held directly between the jaws of a vise. So two short lengths of rubber were cut square at the back end and with a V notch in the other. This gave a very resilient grip on the work and yet held it with considerable firmness.

It often becomes necessary to use the vise in bending strips or small rods into various shapes and forms. Many bends of this kind can be made between two pins held in the vise at proper distances apart. Figure 28 shows how pins for such use are held in a vise by the aid of a small section of rack.

The pitch of the rack must make it possible for the pins to be used in clamping the pins in the right places. As shown, the pins are being used to make series of reverse bends in a flat strip of metal. The pins can be easily spaced at any desired distance by utilizing different teeth in the rack.

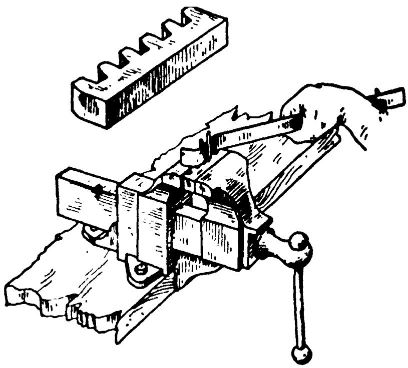


FIG. 28.—Using piece of a rack for bending strips.

Machine vises are also great timesavers when they are well suited to the work to be done. They are necessary on milling machines, shapers, and planers, as well as in some kinds of drilling work. They should be sturdy and capable of holding work against the heaviest cuts likely to be taken. One of the situations to watch in vise work is to prevent the work from working up out of the jaws. Using vises successfully is quite an art. Although most work on the planer is held down on the bed itself, there is much small work where a vise is a great timesaver.

Several methods of clamping thin work in a vise

are illustrated in Fig. 29. The use of parallels will often help in getting the work square and also in holding it firmly in place.

In addition to plain vises there are a number of special ones with swiveling bases, and also with adjustment in two directions that make it possible

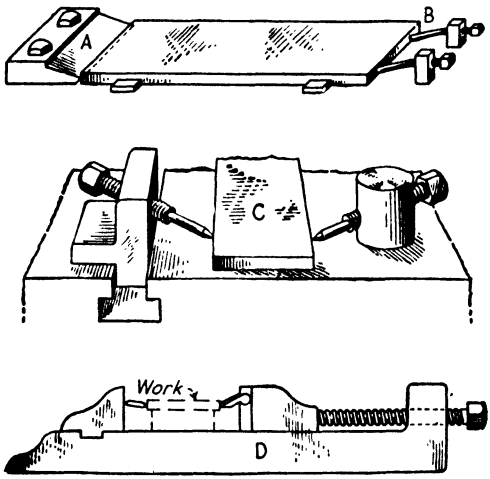


Fig. 29.—Thin work can be held like this.

to hold work in any desired position. These devices run into money and are beyond the small shop in most cases. But if there is much of this fussy angular work to be done, they will be a good investment. One of these vises is shown in Fig. 30 to give an idea of their usefulness where they are needed. This shows the use of a parallel under the work *W* and of a round bar at *A* to ensure a good contact between the jaw and the work.

Figure 31 shows two methods of holding round bars. The single bar is held by a special angular

block and clamp set in the table. When two bars are clamped, a plain strip is placed between them.

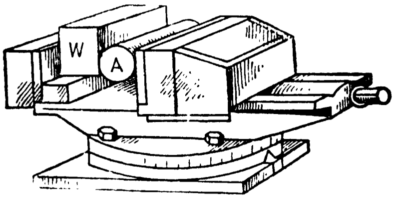


FIG. 30.—Holding work in a chuck.

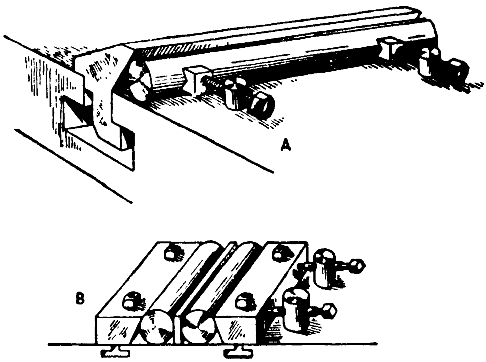


FIG. 31.—Methods of clamping round bars.

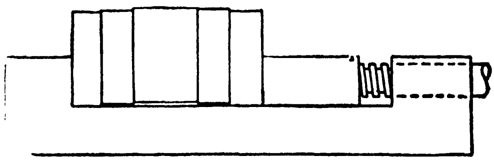


FIG. 32.—How pieces work up out of vise jaws.

In all vise work it is well to avoid overhang of work as much as possible and to take all precautions to prevent work from creeping out of the vise jaws. Figure 32 shows how this may happen.

Keeping Hammer Heads Tight.—Loose hammer heads are not only an annoyance but a real danger and may cause unnecessary accidents that might injure workers and do considerable property damage. A hammer handle that fits as it should can be put in the head to stay by making two saw cuts at right angles and putting in a short but stocky wood screw as shown in Fig. 33. The screw spreads

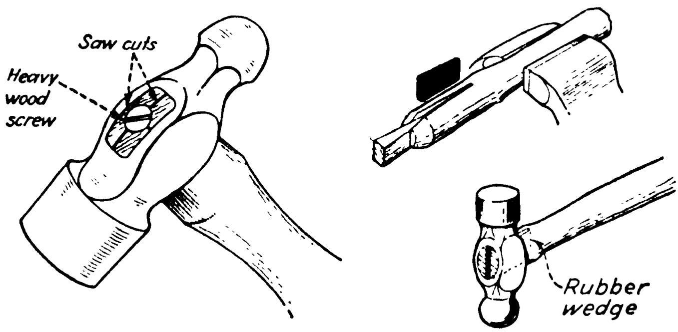


FIG. 33.—Two ways of keeping hammer heads tight.

the end of the handle in four directions and holds the head firmly in place. Space for the screw head should be countersunk so that it will come flush with the end of the handle. Check the screw occasionally to be sure that it is not backing out.

Another method is also suggested as shown in Fig. 33. Here the end of the handle is tapered, and a single saw slot made as shown. The ends of the slot are spread open with a wedge, and a rubber strip or wedge is put in as seen. The handle is then driven into the hammer head until the tapered end projects and the taper part is sawed off. It is said

that the pressure of the rubber wedge will hold the head in place. The other method is somewhat simpler and should hold at least as well.

Hammer-handle Magnet.—Assembling or disassembling motors and other kinds of machines in-

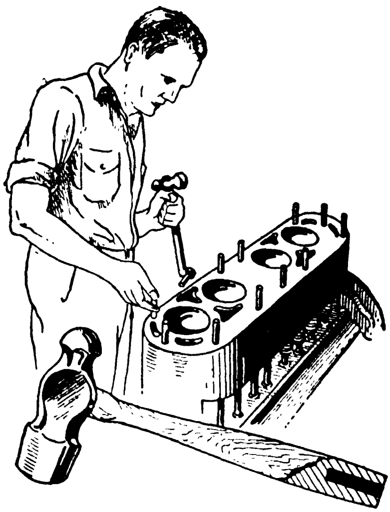


FIG. 34.—A magnet in the end of a hammer handle helps in many cases.

volves the handling of a quantity of small screws and other parts. These frequently have a way of disappearing inside the motor or other machine where they are frequently hard to rescue and take considerable time.

It is very convenient to have a magnet stuck in the end of a hammer handle, as shown in Fig. 34, or any other piece that can be used to fish down into the motor and pick up the small pieces that disap-

pear in its interior. A magnet strong enough to pick up small screws and nuts can easily be put in the handle, as shown, and will be found very handy and save time and annoyance.

Homemade Gear Puller.—Whether you like it or not, the chances are that you will have to make several appliances in your own shop to conserve

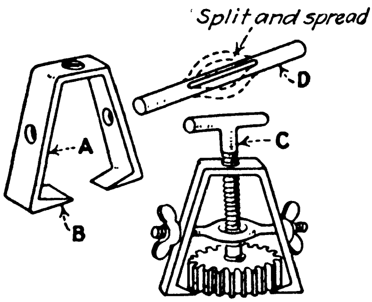


FIG. 35.—A homemade gear puller that works.

capital for things that must be bought. In internal-combustion engine work a gear puller is frequently needed, and one can be made without too much difficulty. The yoke *A* in Fig. 35 was made from ¼- by 1½-in. steel with the ends beveled as at *B* to get into a narrow space behind the gear. The center of the yoke was drilled and tapped for the pull screw *C*. The crossbolt for adjusting the spread of the points was made by splitting the rod, which can be ⅝- or ¾-in. soft steel rod, and opening it out enough to go around the pull screw. As the ends go through holes drilled in the side members which have opened out to put the crossbolt in place, the holes drilled have to be considerably larger than

the diameter of the bolt. Gear pullers of various sizes can be bought from supply stores.

Key Puller.—Another tool along the same line is shown in Fig. 36. This is used to pull the keys that are frequently used to hold pulleys on shafts of various kinds. The main feature is the weight that slides on the rod attached to the hook that

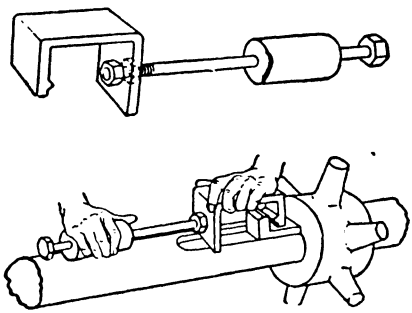


FIG. 36.—A simple key puller and how it is used.

goes over the head of the key. With a fairly heavy weight and a movement of several inches, considerable pressure can be applied by bringing the weight back against the nut or bolthead on the end of the rod. This acts as a sledge hammer and will jar almost anything loose in the way of a key or similar part.

Two-man Tote Box.—Two-man tote boxes are usually made with handles fastened across the ends or sides, as shown by the dotted lines in Fig. 37. These handles are in the way when the box is not being used and take up considerable space when the boxes are stacked or stored.

By using two pipes of suitable size and providing

holes in the boxes as shown in the same figure, handles are provided when needed which can be pulled out when the boxes are set down. This saves considerable floor space and makes one set of

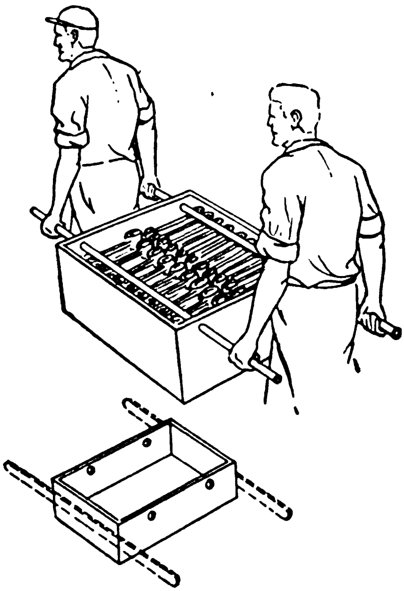


FIG. 37.—A tote box with removable handles.

handles do for a large number of boxes. As there are no projections for anyone to fall over, this makes them safer in every way.

Roller Rests for Tubular Work.—In cutting up pipe with a torch or by any other means that requires rotating the pipe, Fig. 38 shows a simple way of making a stand or rest on which it can be easily turned. Two old roller skates fastened upside down on a bench make a very convenient rest for the pipe,

or any round body that is not too large in diameter. By adding a sort of brake in the shape of a strap around the pipe, the tube can be held in any desired position while it is being cut with a hacksaw instead of a torch or while any other work is done on it.

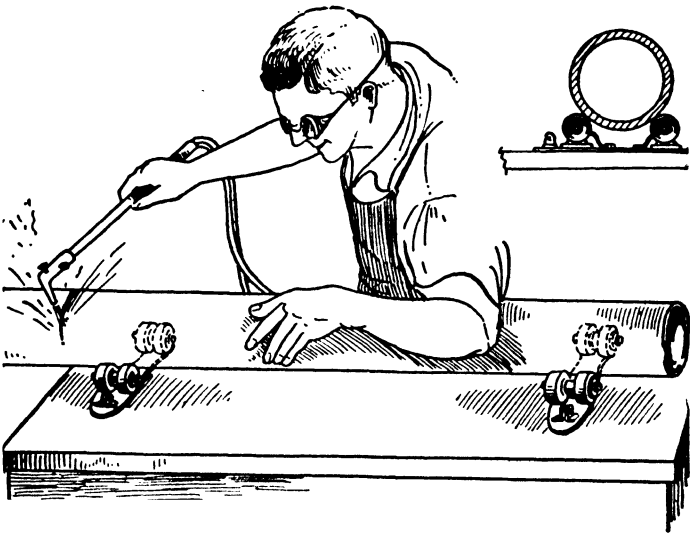


FIG. 38.—Old skates make a roller rest for pipe work.

Discarded roller skates may help solve several problems of this kind in the small shop.

Pads for C Clamps.—There are many kinds of work where C clamps are very convenient to use but where the work would be marred by the clamp and the screw. Figure 39 shows how small hardwood blocks, about 3 in. square by ½ in. thick, are used as pads over both clamp faces. Spring clips shaped as shown in the sketch hold the block over the clamp and make it easy to use on any kind of

work. The blocks can be easily and quickly removed when the clamp is wanted for use in the regular way.

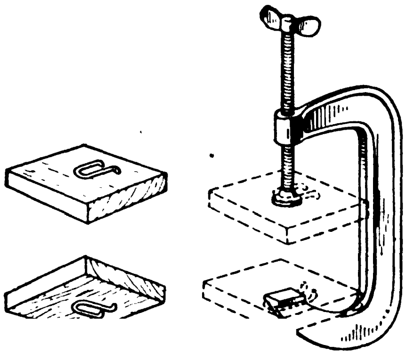


FIG. 39.—Pads prevent clamp from marring the work.

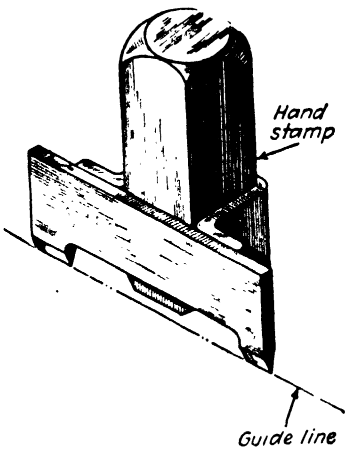


FIG. 40.—Guide for lining up hand stamps.

Lining Up Hand Stamps.—Marking a piece of metal with a hand-stamping outfit and maintaining

alignment of the different letters require more care and skill than the average workman has to offer. The little device shown in Fig. 40 makes it comparatively easy to do stamping with very good alignment and at satisfactory speed.

The guide shown has a socket or opening which is a fairly good fit around the stamp to be used. It also has a straight bar with a knife-edge at each end to follow the line of marking to be done. With this guide and with careful attention to the guides and the line scribed on the work, it is comparatively easy to do stamping that is pleasing to the eye, and at a very good rate.

CHAPTER V

DRILLS AND DRILLING

Drilling is probably the most common operation in the average machine shop, regardless of its size, and a good supply of twist drills is a great convenience. In addition to having standard drills for the regular sizes of holes, it is necessary to have drills that can be used when drilling for tapping. In many cases regular sized drills are right for this work, especially if the tapped holes are not made with a full thread, which is unnecessary in most cases. A thread of three-quarter depth or less is all that is needed in average work. In fact, tests have been made with bolts in nuts having only half a thread in depth and the bolts pulled in two before the threads in the nut stripped. These were in steel. When a steel bolt is screwed into aluminum, the thread in the aluminum should be nearly full depth.

In order to make it unnecessary to carry such a large stock of drills as formerly, one of the standardization committees made a list of drills between 0.0156 and ½ in. diameter, which greatly reduced the number formerly called for, some of which overlapped and caused confusion. This list is for straight-shank drills, the kind most commonly used, and is given in Table 2. This also gives the two lengths of drills made in this series, there being two series so that deep-hole drilling can be done with

standard drills. Tap drills are given in Table 3 and will be found very convenient. These drills give a thread approximately three-fourths of full depth.

Twist drills are of course made in sizes far above ½ in. Diameters up to 2 in. are common and are made up to 4 in. by most drill makers. Some of the drill points used for different materials are shown.

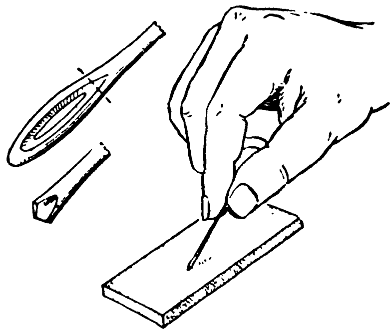
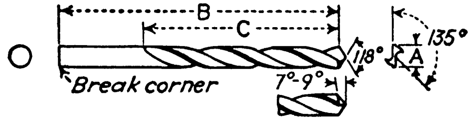


FIG. 41.—Making a small flat drill from a sewing needle.

Flat Drills.—Although twist drills are generally used in the modern shop, there are still places where the flat drill will be found useful. This is true of many odd sizes, especially where the holes are not deep and the size is not too important. Flat drills are regularly made in diameters from 0.002 up to 0.080 in., for watch and instrument makers. Twist drills are also made as small as 0.004 in. for special work. Small flat drills are frequently made from needles by breaking them off at the end and shaping the end to the right cutting angles as in Fig. 41. This shaping can be done on a very fine-grit grinding wheel or on an abrasive stone or perhaps a little

TABLE 2.—PREFERRED SIZES OF STRAIGHT-SHANK DRILLS



Size	Regular series		Long series		Size	Regular series		Long series	
	Drill length	Flute length	Drill length	Flute length		Drill length	Flute length	Drill length	Flute length
A	*B*	*C*	*B*	*C*	*A*	*B*	*C*	*B*	*C*
0.0156	1	1/4			0.0906	2 1/4	1 3/16		
0.0180	1	1/4			0.0937	2 1/4	1 3/16		
0.0200	1	1/4			0.0960	2 1/2	1 3/8		
0.0225	1	1/4			0.0995	2 1/2	1 3/8		
0.0240	1	1/4			0.1024	2 1/2	1 3/8		
0.0260	1 1/4	7/16			0.1040	2 1/2	1 3/8		
0.0280	1 1/4	7/16			0.1063	2 1/2	1 3/8		
0.0295	1 1/4	7/16			0.1094	2 1/2	1 3/8		
0.0312	1 1/4	7/16			0.1130	2 3/4	1 9/16		
0.0330	1 1/4	7/16			0.1160	2 3/4	1 9/16		
0.0350	1 1/4	7/16			0.1200	2 3/4	1 9/16		
0.0370	1 1/2	5/8			0.1220	2 3/4	1 9/16		
0.0390	1 1/2	5/8			0.1250	2 3/4	1 9/16	4 3/4	2 1/2
0.0410	1 1/2	5/8			0.1285	3	1 3/4	5	2 13/16
0.0430	1 1/2	5/8			0.1299	3	1 3/4	5	2 13/16
0.0453	1 1/2	5/8			0.1339	3	1 3/4	5	2 13/16
0.0469	1 1/2	5/8			0.1360	3	1 3/4	5	2 13/16
0.0492	1 1/2	5/8			0.1378	3	1 3/4	5	2 13/16
0.0512	1 3/4	13/16			0.1406	3	1 3/4	5	2 13/16
0.0531	1 3/4	13/16			0.1440	3 1/4	1 15/16	5 1/4	3 1/8
0.0550	1 3/4	13/16			0.1470	3 1/4	1 15/16	5 1/4	3 1/8
0.0571	1 3/4	13/16			0.1520	3 1/4	1 15/16	5 1/4	3 1/8
0.0591	1 3/4	13/16			0.1562	3 1/4	1 15/16	5 1/4	3 1/8
0.0610	1 3/4	13/16			0.1610	3 1/2	2 1/8	5 1/2	3 7/16
0.0625	1 3/4	13/16			0.1660	3 1/2	2 1/8	5 1/2	3 7/16
0.0650	2	1			0.1693	3 1/2	2 1/8	5 1/2	3 7/16
0.0670	2	1			0.1719	3 1/2	2 1/8	5 1/2	3 7/16
0.0700	2	1			0.1730	3 1/2	2 1/8	5 1/2	3 7/16
0.0730	2	1			0.1770	3 1/2	2 1/8	5 1/2	3 7/16
0.0760	2	1			0.1800	3 3/4	2 5/16	5 3/4	3 11/16
0.0781	2	1			0.1850	3 3/4	2 5/16	5 3/4	3 11/16
0.0810	2 1/4	1 3/16			0.1875	3 3/4	2 5/16	5 3/4	3 11/16
0.0827	2 1/4	1 3/16			0.1910	3 3/4	2 5/16	5 3/4	3 11/16
0.0860	2 1/4	1 3/16			0.1935	3 3/4	2 5/16	5 3/4	3 11/16
0.0890	2 1/4	1 3/16			0.1960	3 3/4	2 5/16	5 3/4	3 11/16

TABLE 2.—PREFERRED SIZES OF STRAIGHT-SHANK DRILLS —*Continued*

Size	Regular series		Long series		Size	Regular series		Long series	
	Drill length	Flute length	Drill length	Flute length		Drill length	Flute length	Drill length	Flute length
A	*B*	*C*	*B*	*C*	*A*	*B*	*C*	*B*	*C*
0.1990	4	$2\frac{9}{16}$	6	$3\frac{15}{16}$	0.3125	5	$3\frac{5}{8}$	7	$4\frac{11}{16}$
0.2031	4	$2\frac{9}{16}$	6	$3\frac{15}{16}$	0.3160	5	$3\frac{5}{8}$	7	$4\frac{11}{16}$
0.2090	4	$2\frac{9}{16}$	6	$3\frac{15}{16}$	0.3230	5	$3\frac{5}{8}$	7	$4\frac{11}{16}$
0.2130	4	$2\frac{9}{16}$	6	$3\frac{15}{16}$	0.3281	5	$3\frac{5}{8}$	7	$4\frac{11}{16}$
0.2187	4	$2\frac{9}{16}$	6	$3\frac{15}{16}$	0.3320	5	$3\frac{5}{8}$	7	$4\frac{11}{16}$
0.2244	$4\frac{1}{4}$	$2\frac{13}{16}$	$6\frac{1}{4}$	$4\frac{1}{8}$	0.3390	5	$3\frac{5}{8}$	7	$4\frac{15}{16}$
0.2283	$4\frac{1}{4}$	$2\frac{13}{16}$	$6\frac{1}{4}$	$4\frac{1}{8}$	0.3437	$5\frac{1}{4}$	$3\frac{7}{8}$	$7\frac{1}{4}$	$4\frac{15}{16}$
0.2344	$4\frac{1}{4}$	$2\frac{13}{16}$	$6\frac{1}{4}$	$4\frac{1}{8}$	0.3480	$5\frac{1}{4}$	$3\frac{7}{8}$	$7\frac{1}{4}$	$4\frac{15}{16}$
0.2402	$4\frac{1}{4}$	$2\frac{13}{16}$	$6\frac{1}{4}$	$4\frac{1}{8}$	0.3543	$5\frac{1}{4}$	$3\frac{7}{8}$	$7\frac{1}{4}$	$4\frac{15}{16}$
0.2460	$4\frac{1}{4}$	$2\frac{13}{16}$	$6\frac{1}{4}$	$4\frac{1}{8}$	0.3594	$5\frac{1}{4}$	$3\frac{7}{8}$	$7\frac{1}{4}$	$4\frac{15}{16}$
0.2500	$4\frac{1}{2}$	$3\frac{1}{8}$	$6\frac{1}{2}$	$4\frac{5}{16}$	0.3680	$5\frac{1}{4}$	$3\frac{7}{8}$	$7\frac{1}{4}$	$4\frac{15}{16}$
0.2520	$4\frac{1}{2}$	$3\frac{1}{8}$	$6\frac{1}{2}$	$4\frac{5}{16}$	0.3750	$5\frac{5}{8}$	$4\frac{1}{8}$	$7\frac{5}{8}$	$5\frac{1}{8}$
0.2570	$4\frac{1}{2}$	$3\frac{1}{8}$	$6\frac{1}{2}$	$4\frac{5}{16}$	0.3860	$5\frac{5}{8}$	$4\frac{1}{8}$	$7\frac{5}{8}$	$5\frac{1}{8}$
0.2610	$4\frac{1}{2}$	$3\frac{1}{8}$	$6\frac{1}{2}$	$4\frac{5}{16}$	0.3906	$5\frac{5}{8}$	$4\frac{1}{8}$	$7\frac{5}{8}$	$5\frac{1}{8}$
0.2656	$4\frac{1}{2}$	$3\frac{1}{8}$	$6\frac{1}{2}$	$4\frac{5}{16}$	0.3970	$5\frac{5}{8}$	$4\frac{1}{8}$	$7\frac{5}{8}$	$5\frac{1}{8}$
0.2720	$4\frac{1}{2}$	$3\frac{1}{8}$	$6\frac{1}{2}$	$4\frac{5}{16}$	0.4062	$5\frac{5}{8}$	$4\frac{1}{8}$	$7\frac{5}{8}$	$5\frac{1}{8}$
0.2770	$4\frac{1}{2}$	$3\frac{1}{8}$	$6\frac{1}{2}$	$4\frac{5}{16}$	0.4219	$5\frac{5}{8}$	$4\frac{1}{8}$	$7\frac{5}{8}$	$5\frac{1}{8}$
0.2812	$4\frac{3}{4}$	$3\frac{3}{8}$	$6\frac{3}{4}$	$4\frac{1}{2}$	0.4375	$6\frac{1}{8}$	$4\frac{7}{16}$	$8\frac{1}{8}$	$5\frac{7}{16}$
0.2854	$4\frac{3}{4}$	$3\frac{3}{8}$	$6\frac{3}{4}$	$4\frac{1}{2}$	0.4531	$6\frac{1}{8}$	$4\frac{7}{16}$	$8\frac{1}{8}$	$5\frac{7}{16}$
0.2913	$4\frac{3}{4}$	$3\frac{3}{8}$	$6\frac{3}{4}$	$4\frac{1}{2}$	0.4687	$6\frac{1}{8}$	$4\frac{7}{16}$	$8\frac{1}{8}$	$5\frac{7}{16}$
0.2969	$4\frac{3}{4}$	$3\frac{3}{8}$	$6\frac{3}{4}$	$4\frac{1}{2}$	0.4844	$6\frac{1}{8}$	$4\frac{7}{16}$	$8\frac{1}{8}$	$5\frac{7}{16}$
0.3020	$4\frac{3}{4}$	$3\frac{3}{8}$	$6\frac{3}{4}$	$4\frac{1}{2}$	0.5000	$6\frac{1}{8}$	$4\frac{7}{16}$	$8\frac{1}{8}$	$5\frac{7}{16}$
0.3071	$4\frac{3}{4}$	$3\frac{3}{8}$	$6\frac{3}{4}$	$4\frac{1}{2}$					

coarser grit. Many of these small drills are used in watch and instrument shops and also in the drilling of the spray nozzles for Diesel engines. Those who are accustomed to such small drilling do not consider it anything out of the ordinary. One of the main requirements is a very light drilling spindle, running at high speed and controlled by a sensitive lever so that the operator can feel the resistance of the work to the drill.

TABLE 2A.—BASIC THREAD DIMENSIONS AND TAP DRILL SIZES
AMERICAN THREAD

Nominal size	Outside diameter, in.	Pitch diameter, in.	Root diameter, in.	Commercial tap drill to produce approx. 75% full thread	Decimal equivalent of tap drill
1/16 -64	0.0625	0.0524	0.0422	3/64	0.0469
72	0.0625	0.0535	0.0445	3/64	0.0469
5/64 -60	0.0781	0.0673	0.0563	1/16	0.0625
72	0.0781	0.0691	0.0601	52	0.0635
3/32 -48	0.0938	0.0803	0.0667	49	0.0730
50	0.0938	0.0808	0.0678	49	0.0730
7/64 -48	0.1094	0.0959	0.0823	43	0.0890
1/8 -32	0.1250	0.1047	0.0844	3/32	0.0937
40	0.1250	0.1088	0.0925	38	0.1015
9/64 -40	0.1406	0.1244	0.1081	32	0.1160
5/32 -32	0.1563	0.1360	0.1157	1/8	0.1250
36	0.1563	0.1382	0.1202	30	0.1285
11/64-32	0.1719	0.1505	0.1313	9/64	0.1406
3/16 -24	0.1875	0.1604	0.1334	26	0.1470
32	0.1875	0.1672	0.1469	22	0.1570
13/64-24	0.2031	0.1760	0.1490	20	0.1610
7/32 -24	0.2188	0.1919	0.1646	16	0.1770
32	0.2188	0.1985	0.1782	12	0.1890
15/64-24	0.2344	0.2073	0.1806	10	0.1935
1/4 -20	0.2500	0.2175	0.1850	7	0.2010
24	0.2500	0.2229	0.1959	4	0.2090
27	0.2500	0.2260	0.2019	3	0.2130
28	0.2500	0.2268	0.2036	3	0.2130
32	0.2500	0.2297	0.2094	7/32	0.2187
5/16 -18	0.3125	0.2764	0.2403	F	0.2570
20	0.3125	0.2800	0.2476	17/64	0.2656
24	0.3125	0.2854	0.2584	I	0.2720
27	0.3125	0.2884	0.2644	J	0.2770
32	0.3125	0.2922	0.2719	9/32	0.2812
3/8 -16	0.3750	0.3344	0.2938	5/16	0.3125
20	0.3750	0.3425	0.3100	21/64	0.3281
24	0.3750	0.3479	0.3209	Q	0.3320
27	0.3750	0.3509	0.3269	R	0.3390
7/16 14	0.4375	0.3911	0.3447	U	0.3680
20	0.4375	0.4050	0.3726	25/64	0.3906
24	0.4375	0.4104	0.3834	X	0.3970
27	0.4375	0.4134	0.3894	Y	0.4040
1/2 -12	0.5000	0.4459	0.3918	27/64	0.4219
13	0.5000	0.4501	0.4001	27/64	0.4219
20	0.5000	0.4675	0.4351	29/64	0.4531
24	0.5000	0.4729	0.4459	29/64	0.4531
27	0.5000	0.4759	0.4519	15/32	0.4687
9/16 12	0.5625	0.5084	0.4542	31/64	0.4844
18	0.5625	0.5264	0.4903	33/64	0.5156

Table 2A.—Basic Thread Dimensions and Tap Drill Sizes American Thread—*Continued*

Nominal size		Outside diameter, in.	Pitch diameter, in.	Root diameter, in.	Commercial tap drill to produce approx. 75% full thread	Decimal equivalent of tap drill
9/16	27	0.5625	0.5384	0.5144	17/32	0.5312
5/8	11	0.6250	0.5660	0.5069	17/32	0.5312
	12	0.6250	0.5709	0.5168	35/64	0.5469
	18	0.6250	0.5889	0.5528	37/64	0.5781
	27	0.6250	0.6009	0.5769	19/32	0.5937
11/16	11	0.6875	0.6285	0.5694	19/32	0.5937
	16	0.6875	0.6469	0.6063	5/8	0.6250
3/4	10	0.7500	0.6850	0.6201	21/32	0.6562
	12	0.7500	0.6959	0.6418	43/64	0.6719
	16	0.7500	0.7094	0.6688	11/16	0.6875
	27	0.7500	0.7259	0.7019	23/32	0.7187
13/16	10	0.8125	0.7476	0.6826	23/32	0.7187
7/8	9	0.8750	0.8029	0.7307	49/64	0.7656
	12	0.8750	0.8209	0.7668	51/64	0.7969
	14	0.8750	0.8286	0.7822	13/16	0.8125
	18	0.8750	0.8389	0.8028	53/64	0.8286
	27	0.8750	0.8509	0.8269	27/32	0.8437
15/16	9	0.9375	0.8654	0.7932	53/64	0.8281
1	8	1.0000	0.9188	0.8376	7/8	0.8750
	12	1.0000	0.9459	0.8918	59/64	0.9219
	14	1.0000	0.9536	0.9072	15/16	0.9375
	27	1.0000	0.9759	0.9519	31/32	0.9687
1 1/8	7	1.1250	1.0322	0.9394	63/64	0.9844
	12	1.1250	1.0709	1.0168	1 3/64	1.0469
1 1/4	7	1.2500	1.1572	1.0644	1 7/64	1.1094
	12	1.2500	1.1959	1.1418	1 11/64	1.1719
1 3/8	6	1.3750	1.2668	1.1585	1 7/32	1.2187
	12	1.3750	1.3209	1.2668	1 19/64	1.2969
1 1/2	6	1.5000	1.3917	1.2835	1 11/32	1.3437
	12	1.5000	1.4459	1.3918	1 27/64	1.4219
1 5/8	5 1/2	1.6250	1.5070	1.3888	1 29/64	1.4531
1 3/4	5	1.7500	1.6201	1.4902	1 9/16	1.5625
1 7/8	5	1.8750	1.7451	1.6152	1 11/16	1.6875
2	4 1/2	2.0000	1.8557	1.7113	1 25/32	1.7812
2 1/8	4 1/2	2.1250	1.9807	1.8363	1 29/32	1.9062
2 1/4	4 1/2	2.2500	2.1057	1.9613	2 1/32	2.0312
2 3/8	4	2.3750	2.2126	2.0502	2 1/8	2.1250
2 1/2	4	2.5000	2.3376	2.1752	2 1/4	2.2500
2 3/4	4	2.7500	2.5876	2.4252	2 1/2	2.5000
3	3 1/2	3.0000	2.8145	2.6288	2 23/32	2.7187
3 1/4	3 1/2	3.2500	3.0645	2.8788	2 31/32	2.9687
3 1/2	3 1/4	3.5000	3.3002	3.1003	3 3/16	3.1875
3 3/4	3	3.7500	3.5335	3.3170	3 7/16	3.4375
4	3	4.0000	3.7835	3.5670	3 11/16	3.6875

Flat drills are also used in a variety of ways for rough work where the exact diameter is not important, such as in the blacksmith drilling of rough forgings for boltholes. Drills of this kind can be easily forged in a small forge such as is common in many small shops. Care should be taken to have the cutting lips an equal distance from the center line of the drill as it revolves in the chuck. With a drill well centered and ground to cut freely, the holes will be practically as accurate as those drilled with a twist drill. On deep holes, however, the flat drill does not clear itself so well as the twist drill where the chips flow up the helical flutes. Where the chips curl tightly, however, the twist drill is at a disadvantage as the curling chips may become a nuisance.

Using the Right Drill.—Drilling is the most common operation in nearly all machine shops; the job shop especially uses a wide variety of materials in the course of a year. Jobs may vary from hard steel to plastics, and even slate if there is any switchboard work to be done. For best results it is necessary to use the shape of drill point suited for the work rather than try to drill them all with the standard point of 118 deg. included angle.

Not only is the angle of the drill point important but also the shape of the cutting lip and the thickness of the web, or central part of the drill. Generally speaking, the softer the material to be drilled, the sharper should be the drill point. This is illustrated in Fig. 42 which comes from the Westinghouse Company, which handles a wide variety of

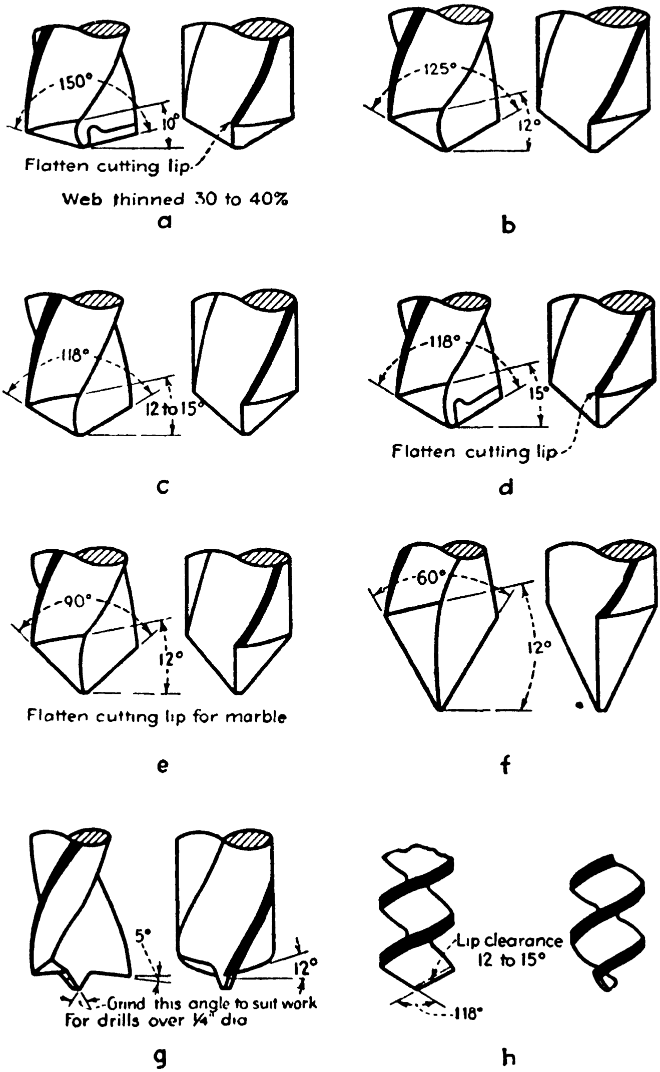


Fig. 42.—Drill points for various materials.

materials. For suggestions as to drilling speeds see Table 3. These are for high-speed drills and are not to be considered as positive for all work.

TABLE 3.—SPEEDS AND FEEDS FOR DRILLS OF HIGH-SPEED STEEL IN VARIOUS METALS WITH A SUITABLE COOLANT

Size of drill	Feed per revolution	Bronze, brass	Alloy-steel drop forging	Cast iron	Tool and carbon-steel drop forgings	Mild steel	Malleable iron	Cast steel	Hard cast iron
Ft. per min.		300	50	140	60	120	90	40	80
In.	In.	R.P.M.							
1/16	0.0030	18,320	3,056	8,554	3,667	7,328	5,500	2,445	4,889
3/32	0.0035	12,212	2,038	5,702	2,442	4,884	3,666	1,628	3,258
1/8	0.0040	9,160	1,528	4,278	1,833	3,667	2,750	1,222	2,445
5/32	0.0045	7,328	1,221	3,420	1,465	2,934	2,198	976	1,954
3/16	0.0050	6,106	1,019	2,852	1,222	2,445	1,833	815	1,630
7/32	0.0055	5,234	872	2,444	1,047	2,094	1,570	698	1,396
1/4	0.0060	4,575	764	2,139	917	1,833	1,375	611	1,222
9/32	0.0065	4,071	678	1,900	814	1,628	1,222	542	1,084
5/16	0.0070	3,660	611	1,711	733	1,467	1,100	489	978
11/32	0.0075	3,330	555	1,554	666	1,332	1,000	444	888
3/8	0.0080	3,050	509	1,426	611	1,222	917	407	815
13/32	0.0085	2,818	469	1,316	563	1,126	846	376	752
7/16	0.0090	2,614	437	1,222	524	1,048	786	349	698
15/32	0.0095	2,442	407	1,140	488	976	732	326	652
1/2	0.0100	2,287	382	1,070	458	917	688	306	611
9/16	0.0105	2,035	339	950	407	814	611	271	543
5/8	0.0110	1,830	306	856	367	733	550	244	489
11/16	0.0115	1,665	277	777	333	666	500	222	444
3/4	0.0120	1,525	255	713	306	611	458	204	407
13/16	0.0125	1,409	234	658	281	562	423	188	376
7/8	0.0130	1,307	218	611	262	524	393	175	349
15/16	0.0135	1,221	203	570	244	488	366	163	326
1	0.0140	1,143	191	535	229	458	344	153	306
1 1/8	0.0150	1,017	170	475	204	407	306	136	272
1 1/4	0.0160	915	153	428	183	367	275	122	244
1 3/8	0.0160	833	139	389	167	333	250	111	222
1 1/2	0.0160	762	127	357	153	306	229	102	204
1 5/8	0.0160	705	118	329	141	282	212	94	188
1 3/4	0.0160	654	109	306	131	262	196	87	175
1 7/8	0.0160	610	102	285	122	244	183	81	163
2	0.0160	571	95	267	115	229	172	76	153

The angle of the point varies and also the cutting angle to which the point is ground. The 118-deg. angle is considered best for general work, for deep holes in soft steel, and for tool steel, nickel, and manganese alloys. The use of each type of point as shown in each of the nine drill points illustrated in Fig. 42 follows.

In Fig. 42 the drill point *A* is recommended for hard material such as manganese steels; *B* is for

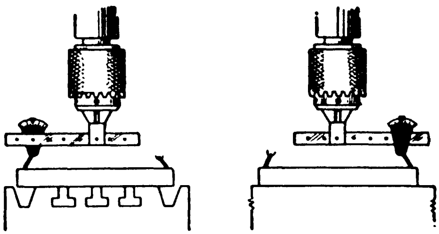


FIG. 43.—Checking squareness of drill table.

heat-treated steels, drop forgings, and alloy steels in the 240 Brinell hardness range; *C* is standard for general work in soft steel, steel castings, and annealed tool steels; *D*, with a similar angle but a flattened cutting lip, works well in brass of various kinds; *E* is used for aluminum, marble, and plastics; *F* is a modification of *E* with a sharper point for wood and softer metals; *G* is a special point for sheet metals, copper, fiber, plastics, and wood; *H* is for drilling slate as used in switchboard work.

Checking Squareness of a Drill Table.—An easy way to be sure that the table is square with the drilling spindle is shown in Fig. 43. Simply clamp an arm in the drill chuck and fasten a sensitive dial gage at the end. A round bar bent at right angles

will answer for the arm. Contact can be made with the work itself, or with parallels laid on the table. By checking at four points, 90 deg. apart, any deviation is easily detected. It is necessary that the table be square with the spindle to secure satisfactory work from the machine.

For the Drill Press.—Holding work under the drill is not always easy, especially when it is in the shape

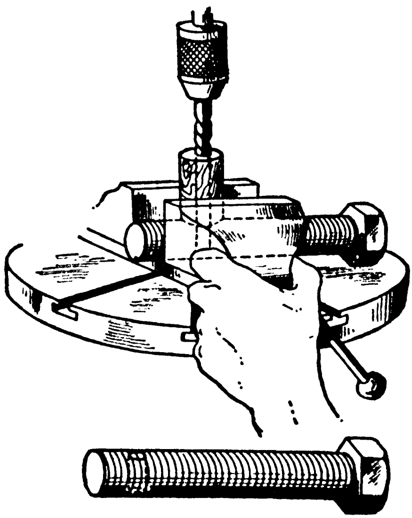


Fig. 44.—Using a wooden dowel rod as a drill bushing.

of round bars. One shop had to drill cotter-pin holes in the ends of a number of bolts and had no drill jig for the job. To prevent the drill from running off the bolt they took pieces of dowel rod from the pattern shop a little larger in diameter than the bolt and about 1 in. long. They clamped the bolt and the piece of dowel rod in the vise as shown in Fig.

44 and drilled through the dowel rod into the bolt. The dowel acted as a guide for the drill and prevented it from running off the bolt until it had made a good center for itself. With a hardwood dowel the same one will answer for several bolts.

Another drill guide is shown in Fig. 45 where a piece of angle steel has holes drilled in it to act as a drill guide. These holes are easily drilled from

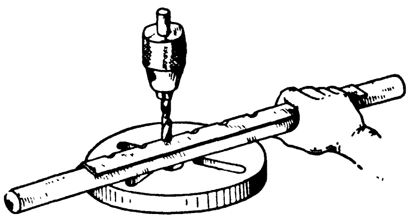


FIG. 45.—An angle iron with holes in the angle acts as a guide.

inside the angle; when the angle is placed over a round shaft, it centers the drill until it enters the work.

Keeping Drill Chips on the Outside.—It is sometimes necessary to drill into a tube or other hollow piece where it is difficult to clean the chips out of the center if the drill goes through the pipe wall. A suggestion is to use some sort of sticky substance on the point of the drill so that the chips will cling to it instead of falling inside the pipe. Any heavy-bodied and sticky substance can be used, such as heavy oil of high viscosity. One suggestion is to use molasses to catch and hold the chips. If the hole can be drilled from the underside, as is sometimes the case, the chips will fall away from the

work and no further precaution is necessary. Figure 46 shows a hand drill where molasses was used.

Boring in a Drill Press.—Small shops will find that a large variety of work can be done on the drill press if other machines are not available. The example shown in Fig. 47 is an extreme case and is not recom-

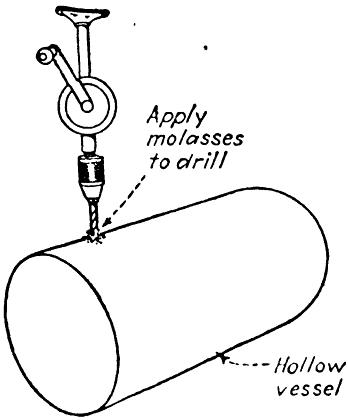


FIG. 46.—Preventing chips from getting inside the work.

mended as a regular operation because of the tooling necessary. Many old shops have used similar methods to keep production going when more suitable machines were not available.

This would normally be a face-plate job on a lathe or boring mill as the work could all be done with single-point tools. But by using the boring bar shown all the operations were done at once as there were a number of pieces to be machined. A bracket extending from the drill-press column carried a guide for the boring bar, and a similar guide was provided for the lower end of the bar. This

guide had to clear the support under the table, which is not shown. In some machines the lower guide could not be bolted under the table as shown.

The boring bar carried four cutters, which were much better supported than indicated by the sketch. As shown, there are two cutters for boring the cored

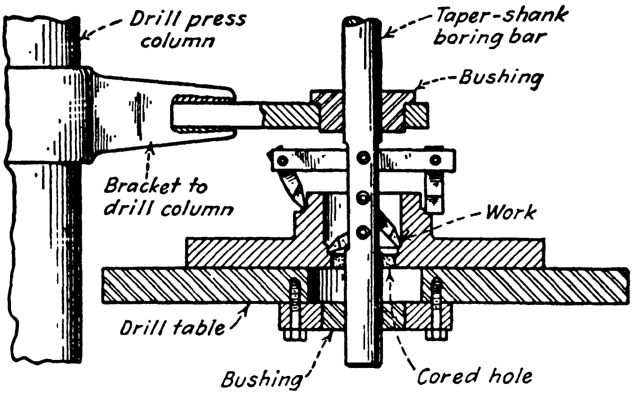


FIG. 47.—Using a drill press to bore and turn a special job.

hole and two for turning the outside of the hub. Many small production jobs have been turned out with makeshift devices of this kind and kept the small shop going until more suitable machines could be purchased.

CHAPTER VI

FILING AND SAWING

Files form an important part of the tool equipment of a small shop. Much of the work of such shops consists of fitting new parts into old machines, in "cutting and trying" which is not done where machines or other articles are regularly made. A good file, in the hands of a man who knows how to use it, can work wonders in shaping parts to fit each other. For best results it must be the right kind of file. And because there are so many uses for files in the small job shop, it will save time and dollars to have a wide assortment of files and to keep them where they can be easily found, as well as in good condition.

Figure 48 shows the teeth on different files in their actual sizes.

Rough files, those with the coarsest teeth, should be handled carefully. A few careless strokes on hard material can knock out enough teeth to shorten their useful life greatly. For "snagging" rough, hard castings, use an old file if a coarse grinding wheel is not available. Rough files are particularly useful on the softer metals where considerable stock must be removed. Some brasses have a sort of slippery surface that requires sharp teeth to give a good bite. Files that seem to slide over such sur-

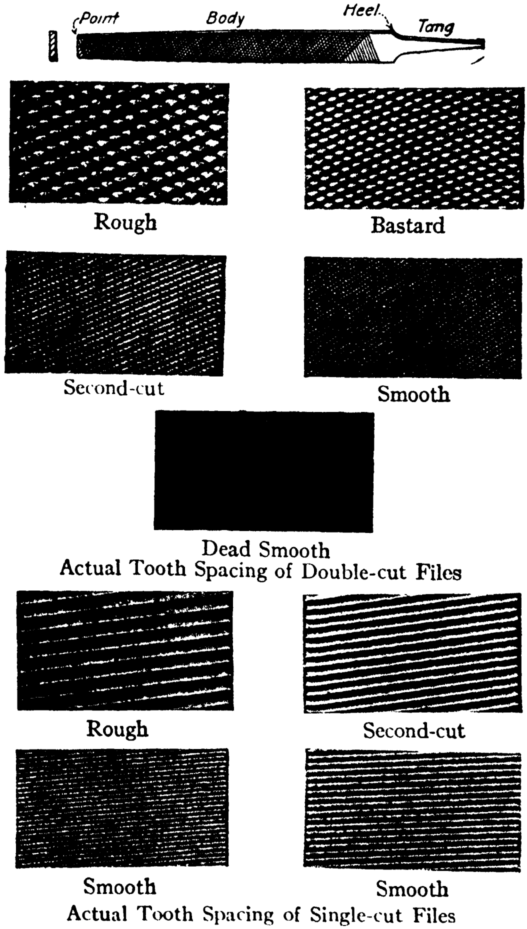


FIG. 48.

faces will often cut very well on steel or iron that is soft enough to be filed at all.

In filing soft metals, such as aluminum or babbitt, the teeth clog easily and, as the chip space is filled,

the file slides over instead of cutting. It will usually help to rub chalk over the file partly to fill the chip space, as this seems to prevent the metal from clinging to the file. Some metals, however, make chips that have almost to be dug out from between the teeth. A file card or wire brush will help in most cases, but a flattened nail end, with teeth made by the file itself, may be found necessary to remove the chips. Oil is sometimes put on the file, but this has a tendency to make the tool slip over the work.

For rough filing the double-cut file will remove metal faster. For smoother work the single-cut is better. It is also better where work is filed in a lathe, although this is not the best way of getting a good fit. Although some files are advertised for use especially in the lathe, this practice is not to be recommended if round work is needed. The variations in the metal at different points and the difference in the pressure exerted at different points of the stroke both tend to remove unequal amounts at different parts. There are many jobs where exact roundness is not necessary and the finishing can be done by filing, but this is not to be recommended for general use.

The curved-tooth file is particularly good for removing considerable metal from soft materials such as aluminum or babbitt. It gives a shearing cut and usually clears itself of chips. This was originally called a "Vixen" file and was made in Philadelphia. This type of file is now made by several concerns.

A great variety of files are now made, each having

some advantage for special uses. They should be chosen carefully in view of the kind of work most likely to be done. The bastard file, which is between the roughing file and the second-cut, is perhaps of most use on rough work, being somewhat finer than the roughing file. The second-cut is also very useful as is the smooth file for finishing. The dead-smooth file is seldom used because it is so fine as to remove very little metal. Its use is confined largely to steel and to drawfiling, which is filing lengthwise of a piece instead of across it. It is done by moving the file, held in both hands, along the surface in the opposite direction from usual filing practice.

Safe-edge files, those with no teeth on the edges, are very useful in some places. For filing close to a shoulder, without filing the shoulder itself, it is both safe and convenient. Some files have rounded edges with teeth, without teeth on the sides. They are handy for filing slots as the plain sides act as guides and also make it easier to control the width of the slot. There are also various files made especially for diesinkers to enable them to work down in cavities of the dies. Some have the ends bent in a curve for working out a radius below the surface. These are called "riffles" in some shops and are very convenient. Many of these are known as Swiss files, either from originating in Switzerland or being made there.

Although it is not necessary for the small shop to stock up with a wide variety of files, buying only those needed for the kind of work that is likely to come in at the beginning, it is well to know of the

other files that can be obtained for special work when it comes. For these, special files can save a lot of time in places where they are needed. Any large filemaker will send a catalogue of the various kinds of files, together with much valuable informa-

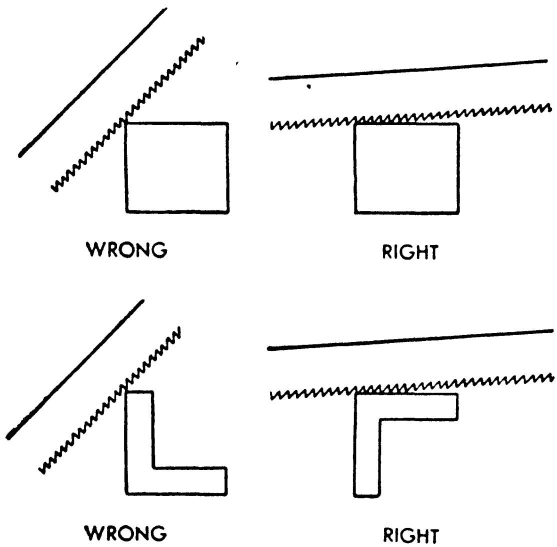


Fig. 49.—The wrong angular contact of saw blades breaks teeth and costs money.

tion as to their use. It will pay to have this for your own information and for your men.

Knowledge and experience in filing are not nearly so essential now as in the shops of 50 years ago. Then it was a very necessary part of the trade for every machinist to know how to file accurately and to file surfaces that were really flat.

Hacksaws.—Hacksaws are a very important tool in any small shop, and both time and blades can be

saved by selecting the best blades for each kind of work and then using it properly. Pipe or tubing should be cut with a fine-tooth saw, from 24 to 32 teeth per inch, the finer teeth for tubes with thin walls.

TABLE 4.—RECOMMENDED TEETH AND SPEEDS FOR HAND-OPERATED HACKSAWS

Material to be cut	Teeth per in.	Strokes per min.
Aluminum	14	60
Angles, heavy	14	60
Angles, light	18	60
Brass	14	60
Brass tubing*	24	60
Bronze	14	60
BX*	32	60
Conduit, rigid*	24	60
Drill rod	18–24	40
Iron, cast	14	60
Pipe*	24	60
Rails	14	60
Sheet metal*	32	60
Steel, high-carbon	18–24	60
Steel, high-speed	18	40
Steel, machinery	14–24	60
Tubing, light*	32	60

* The use of cutting compound is recommended.

The angular contact of a saw with the work is also important, Fig. 49 showing both the right and the wrong methods. Speed is also important, from 40 to 60 strokes per minute, depending on the material. For hard metals 50 strokes a minute is suggested. Table 4 gives recommended blades and speed for hand-operated hacksaws.

For power-operated hacksaws, use the saws and speeds shown in Table 5. For regular band saws quite different recommendations are made. Still

TABLE 5.—RECOMMENDED TEETH AND SPEEDS FOR POWER-OPERATED HACKSAWS

Material to be cut	Teeth	Speed
Aluminum	4–6	120
Babbitt	4–6	120
Brass castings, hard	6–10	120
Brass castings, soft	4–6	120
Bronze castings	4–6–10	90
Copper bars	4–6	90
Copper tubing	10	90
Die blocks*	4–6	60–90
Drill rod*	10	90–120
Forging stock, alloy*	4–6	90
Forging stock, mild*	4–6	90–120
Bronze, manganese	6–10	60–90
Iron, cast	6–10	90–120
Iron, malleable*	6–10	90
Monel metal	6–10	60–90
Nickel alloys*	6–10	60–90
Pipe	6–10	120
Rails*	6–10	60–90
Steel, carbon tool*	6–10	90–120
Steel, high-speed*	6–10	60–90
Steel, machinery*	4–6–10	90–120
Steel, stainless*	6–10	60–90
Steel, structural*	6–10	90–120

* The use of cutting compound is recommended.

higher speeds are used for skip-tooth band saws, as shown in Table 6. In these saws every other tooth is omitted, which is the reason for the higher speeds. These saws clear themselves of chips more readily,

TABLE 6. RECOMMENDED TEETH AND SPEEDS FOR SKIP-TOOTH BAND SAWS

	Teeth per in.	Speed
Metals		
Aluminum	3–4	2,500–3,500
Aluminum, cast	2–3	3,500–4,500
Aluminum forgings	3–4	1,500–2,500
Brass	3–4	1,000–1,500
Copper	3–4	1,000–1,500
Kirksite	3–4	2,500–3,500
Lead	3–4	2,500–3,500
Magnesium	2–4	3,000–4,000
Zinc	3–4	2,500–3,500
Plastics		
Bakelite	3–6	3,000–4,000
Catalin	3–6	3,000–4,000
Fiberglas	3–6	2,000–3,000
Formica	3–6	3,500–4,500
Lucite	2–6	2,500–3,500
Micarta	3–6	3,000–4,000
Wood		
Softwoods	3–6	3,500–4,500
Hardwoods	3–6	3,000–4,000
Plywoods	3–6	3,500–4,500
Miscellaneous		
Asbestos	3–4	750–1,250
Carbon	3–4	2,500–3,500
Celotex	3–4	3,500–4,000
Paper	3–6	1,000–2,000
Masonite die stock	3–6	1,250–2,000
Rubber, hard	3–6	3,000–4,000

TABLE 7.—RECOMMENDED TEETH AND SPEEDS FOR CONVENTIONAL TYPES OF BAND SAWS

	Teeth per in.	Speed of blade, ft. per minute
Nonferrous Metals		
Aluminum, alloy	6–10	1,200
Aluminum, pure	6–8	3,000
Brass castings, hard	8–12	400
Brass castings, soft	8–10	800
Brass tubing	14–18	300
Bronze castings	8–10	400
Bronze, manganese	8–12	150
Copper, drawn	8–10	800
Nickel	10–14	120
Ferrous Metals		
Drill rod	14	100
Iron, cast	10	100–120
Iron, malleable	8–12	150–200
Iron, pipe	10–14	120
Iron sheets	14	100–200
Steel, alloy	10–14	120
Steel, annealed tool	10–14	120
Steel billets	6–8	120
Steel, carbon tool	10–14	120
Steel, cold-rolled	6–8	120
Steel, machinery	8–12	120
Steel, high-speed	10–14	120
Steel, nickel	8–10	120
Steel sheets	12–14	3,000
Steel, stainless	8–10	50–75
Steel, structural	10–12	120
Steel tubing	14–18	150
Miscellaneous		
Asbestos sheets	10	150
Bakelite sheets	14–18	500
Fiber	6–8	500
Slate	8–10	80

NOTE: The correct tooth is determined by the size and shape of material. The higher speed may be safely used on soft metals; the lower speed is recommended for hard and tough materials.

having double space between teeth. These suggestions are made by the W. O. Barnes Co., Inc., Detroit, Mich. Table 7 is for band saws with standard teeth.

Tube Bending.—Bending tubing without undue distortion—usually flattening—requires some means

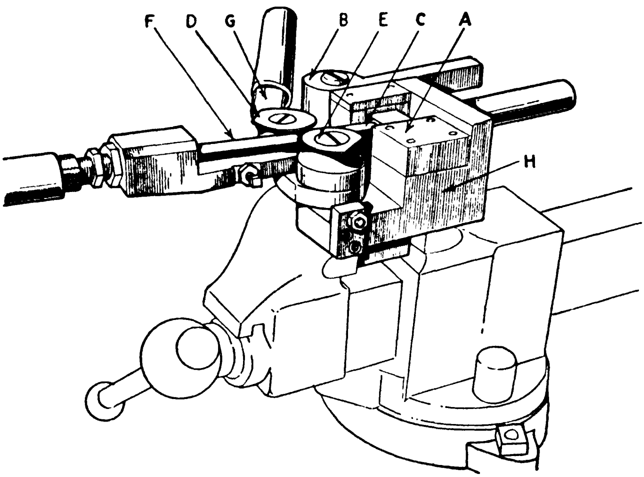


FIG. 50.—Open view of bending fixture.

of preventing collapse. The plumber uses a coil spring inside a lead pipe, but this cannot be done in mass production. Figure 50 shows a fixture used in bending 7/16-in. brass tubing. It incorporates the drawing principle, practically eliminates spring-back after bending, and preserves the full internal area.

The fixture consists of two half-round jaws *A*, which slide by means of a cam *B*. A round-nosed pin *C* goes inside the tube when it is clamped in the jaws. The circular die *D* makes the first bend,

while die *E* makes the second one. A round-nosed forming tool is seen at *F*. Lever arm *G* is pivoted at the center of die *E*. It supports both the die *D* and the tool *F*. All are supported by the body of the fixture *H*.

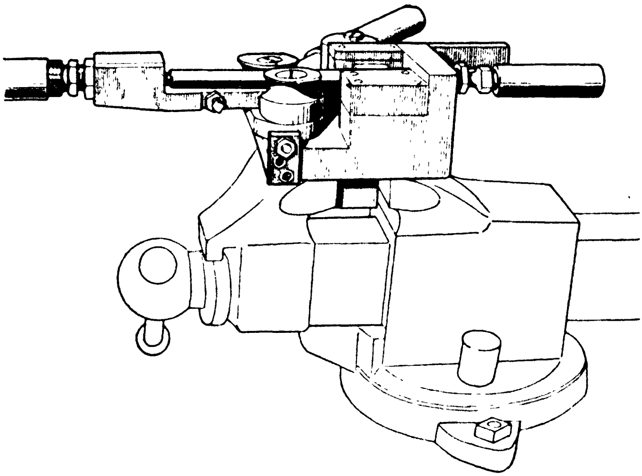


Fig. 51.—Outside rollers and inside mandrels are essential features of fixture.

A straight piece of tubing is slipped over the pin *C* until it strikes a stop, as in Fig. 51. The mandrel *F* is run into the tube until it almost strikes the end of pin *C*. Forcing tool *F* to the left, as in Fig. 52, makes the bend. An adjustable stop allows the distance swung to be set for the spring of different materials. Figure 52 shows how the first bend is completed with the tube pulled off the mandrel *F*.

Lever *G* is now revolved to the position shown in Fig. 53, after the clamp is released and the tube draws off the pin *C*. An adjustable stop, shown at the

right in Fig. 51, limits the final motion. Form tool *F* and pin *C* are withdrawn, and the bent tube is

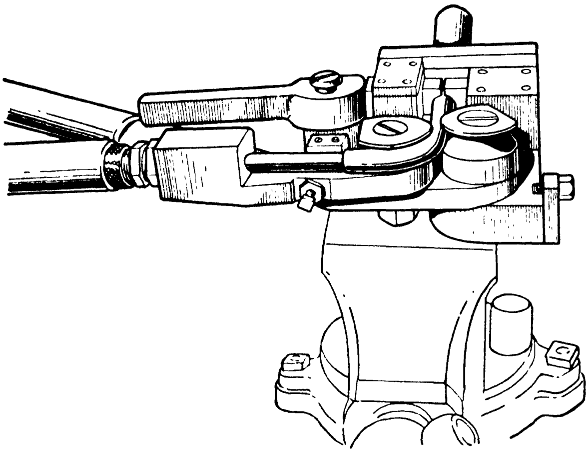


Fig. 52.—Pipe is gradually withdrawn from mandrel as it bends.

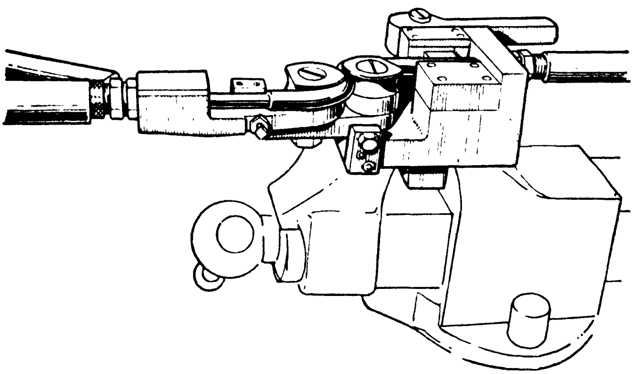


Fig. 53.—A compound bend. The tip of the mandrel remains opposite the center of the formed roll.

removed by threading out from between the circular dies. The spring-back may vary with each batch

of material, and the stops limiting the movements must be adjusted to suit. Dipping the round-nosed pins in lubricant aids the work. They are made of

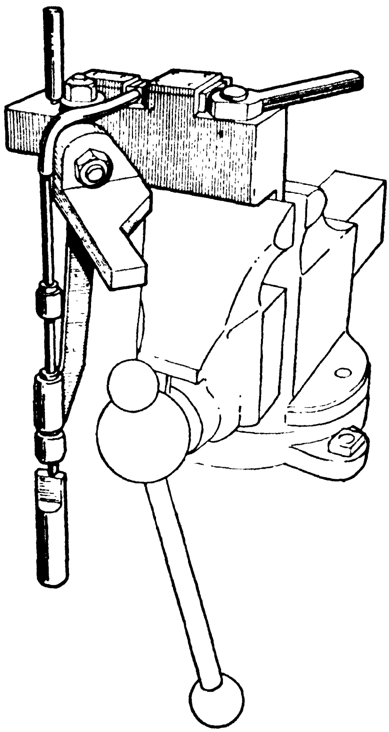


Fig. 54.—This pipe is bent in two places. A different fixture is used.

hard drill rod. Pin *F* should project a short distance beyond the point of tangency of die *D* and *C* a similar distance beyond *E*. They should be slip-fitted in the tube, as should the grooves in the clamps.

By modifying the design, this fixture can be used to bend tubing in two planes, as in Fig. 54. Figure

55 shows how oil assemblies are built for motors. At the left the bend is vertical; at the right it is horizontal, after a slight downward bend. This

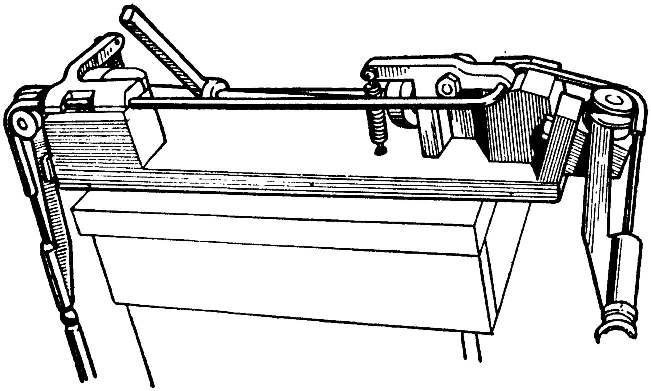


FIG. 55.—Another fixture for oil-line assemblies.

snows clearly how the mandrel is withdrawn as the bend is made but how the end supports the walls against collapse as it turns around the roller guide. These suggestions are made by R. G. Freeman of the General Motors Institute of Technology.

CHAPTER VII

ENGINE LATHE WORK

The engine lathe is probably the most important single machine in the small shop as it can be made to do almost any kind of machine work, from drilling a center hole in a bar to facing a flat surface on work fastened to the face plate. Although the main purpose of the engine lathe may be said to be turning between centers, it has two other regular functions. Work held in a chuck can be drilled, bored, turned, and faced, as well as threaded. The same can be done with work held on the face plate, including many pieces of work that can hardly be held in the standard chuck. Familiarity with both of these methods is particularly useful in any small shop.

Chucks and Chucking.—Good chucks run into real money, and the small shop must not invest too heavily in any one item, as there are so many that must be had in order to handle the variety of work that is likely to come along. Beginning with drill chucks, there are two main features to be considered: accuracy and holding power. For small drills the kind of chuck that can be tightened by hand, or without a wrench, is very convenient. For heavier drilling there are chucks which have a bulldog grip and which can also be used for holding some kinds

of bar work in the lathe spindle. These require sturdy jaws and are tightened by wrenches.

Chucks for lathes vary from the small collet, or draw chuck, which goes in the lathe spindle and holds only one size of work, to the husky chuck that screws on the spindle nose and may easily weigh 50 lb. Chucks vary from two to four jaws, the usual types having either three or four. The chuck with two jaws, with the right- and left-hand screw controlling them, is very strong but is not so much used as formerly. The main choices lie between the three- and four-jawed chucks and between those in which the jaws are independent of each other or where they move together, controlled either by a scroll or by bevel pinions on each chuck jaw and a bevel ring gear that meshes them all together.

For light work where accurate rechucking is not necessary, the three-jawed universal chuck is very convenient. In most cases it will be found that wear and changing adjustments soon create a chuck that will not hold the work dead true in the center. With the independent chuck, two of the jaws can be locked in position and, with only the third jaw moving, it is possible to clamp round work very accurately. Where the work is varied, however, the four-jawed independent chuck has many advantages. It will hold round work as well as the three-jawed chuck, but it will be necessary to loosen two jaws instead of one in chucking round work in the same place.

Chucking work properly is an important part of any job. It must be held true and firm but must

not be distorted by pressure sufficient to hold it in place. It often requires considerable ingenuity to hold odd-shaped work with the chuck and fixtures available. Some work requires straps to hold it back against the chuck, as well as the chuck jaws that hold it against the action of the cutting tools.

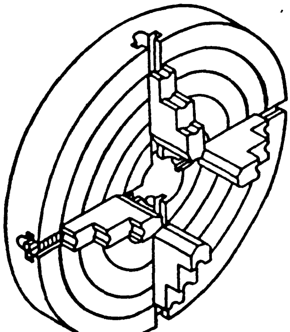


FIG. 56.—Four-jawed independent chuck with reversible jaws.

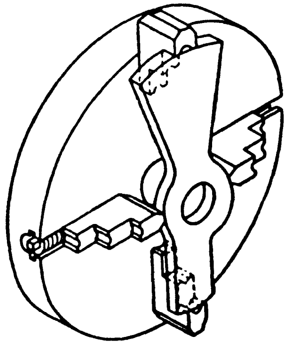


FIG. 57.—Two jaws reversed to hold ends of a long piece. Other jaws hold the sides.

With few exceptions, lathe chucks having jaws that are operated independently, known as "independent chucks," are much more useful for a variety of work than the universal chuck, where all the jaws are moved at the same time. For most work the four-jawed chuck will be found more useful than the three-jawed chuck. Chucks with the step type of jaw, as in Fig. 56, have a wide range of usefulness. Plain round bars or other pieces can be gripped in the jaws in the position shown. Rings or other hollow work can be gripped by the steps in the jaws when the work is placed over them. By reversing two of the jaws, as in Fig. 57, an odd-shaped piece, simi-

lar to the one shown, can be firmly held in position for any kind of machining. Here, too, the steps on the jaws, which grip the ends of the work, act as rests and make it easy to put work squarely in the chuck. This is only one of many combinations that can be made in placing the jaws to hold work of almost any shape or size within the capacity of the chuck.

False or auxiliary jaws can also be fitted over the regular chuck jaws and grip work of almost any kind, either rough or finished. These jaws can be shaped to fit any particular work that may have to be done. They can frequently be of soft metal, cast into plaster molds made from the piece itself. If a large number of the pieces are to be used, the false jaws can be made of cast iron and thus last much longer than jaws of soft metal. If the work requiring these jaws comes from a regular customer, the jaws can be laid aside and properly marked. If and when he orders another batch of work, the old jaws can be trotted out and the work proceed more promptly than the first time.

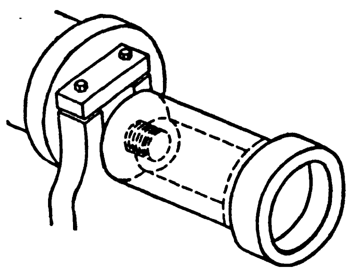


FIG. 58.—Plain chuck screwed on spindle nose to hold special work. Sometimes called a "pot chuck."

Various kinds of chucks can be made for special work such as those shown in Figs. 58 and 59. The first is sometimes called a "pot chuck" and is made to receive the shank of a piece of work that could not

be gripped very firmly by the regular chuck jaws. With this extension the work, or the outer end of the chuck, should be supported by the steady rest. It is good practice to use the steady rest in many cases where the overhang could interfere with securing satisfactory work, for spring of the work, due to the lifting action of the cutting tools, not only interferes with securing satisfactory work but is also hard on the lathe spindle. The chuck in Fig. 59 is for driving flat work and is useful in turning flat cutters used in boring bars and similar work.

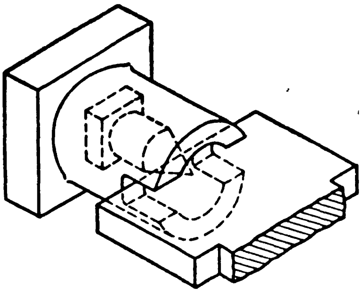


FIG. 59.—Another special chuck to drive flat cutters.

Many small lathes, and some of larger sizes, are supplied with collets, or collet chucks, as seen in the next three figures. Each is intended for only one size of work and is not especially necessary in most jobbing work. If standard-diameter bars are to be used in work of any kind, these collets are very useful as they hold the bars accurately and are easily handled.

Figure 60*a* is for small round bars, such as drill rod. The rod is gripped by closing the jaws, which are split, by screwing the taper collar over them. This action is reversed in the chuck shown in Fig. 60*b* as here the work is held in the outside of the chuck, the split jaws being spread by screwing in the taper plug. A more complete design of collet chuck is seen in

Fig. 61. The chuck body *B* screws on the spindle nose *A* and the work is held by screwing the nut *C* over the fine thread at the end of the chuck body.

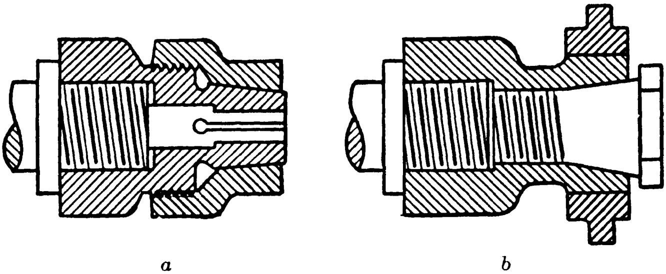


FIG. 60.—Two special chucks. The collet chuck on the left screws on a lathe spindle nose. The one on the right expands to hold hollow work for turning.

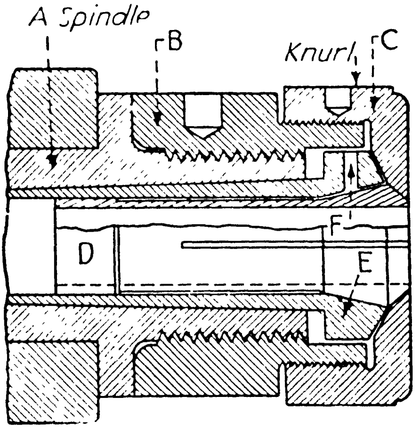


FIG. 61.—A collet chuck that can use different sleeves.

Inside the taper hole in the spindle is a sleeve *E* which is hardened and ground. The sleeve *D*, which holds the work, fits inside sleeve *E*. The outer end

of *D* has two tapers, one mating sleeve *E* and the other the sharper taper in the mouth of nut *C*. Screwing in nut *C* forces the end of *E* against the longer taper and compresses this sleeve on the work.

With a number of sleeves of different sizes this chuck can be made to serve for holding a wide range of sizes within its capacity. The arrow *F* shows a pin which keeps sleeve *E* from turning in the outer sleeve, which remains in the spindle when the collet is in use.

In shops where there are several lathes with spindle noses of different sizes it is convenient to be able to use the chucks on any lathe. This can be done by making a few chuck adapters as seen in Fig. 62. These can be of cast iron. The flange next to the headstock should be square or flattened to afford a good grip for a wrench in removing the adapters. It must be remembered that, when chucks are changed from one lathe to another, they are not likely to run exactly the same on each. But with independent-jawed chucks this is of no consequence, as the jaws can easily be adjusted so as to make the work run true in any of the lathes with any of the chucks.

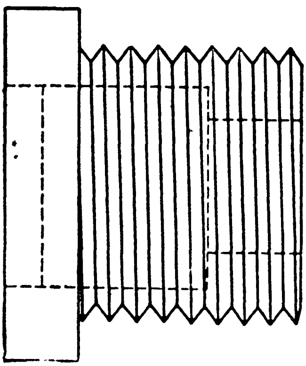


Fig. 62.—Adapter to hold chucks from larger spindles.

Face-plate Work.—Many kinds of lathe work can be done by using the face plate of the lathe instead

of attempting to hold the work in chucks. In some shops it is customary to speak of "chucking the work on a face plate," which means fastening the work to the face plate by straps or clamps of various kinds. One of the first requirements for accurate face-plate work is that the face plate itself be square with the lathe spindle. With face plates that screw on the spindle nose and bear against a narrow collar it is easy for the face plate to get "out of square," in shop language. A very small piece of dirt or chip between the collar and the face plate will throw the plate out and may lead to disappointment in the resulting work.

Precision bench lathes usually mount the face plate on a tapered surface, which is more dependable than the square shoulder. Where the face plate is not square with the spindle, it should be made so before accurate work is attempted. This refers primarily to work that is clamped to the face plate and depends on its being square to ensure any work done on the piece being at right angles to the face clamped against the plate.

Where there is any doubt as to the plate's being square, this can easily be tested with almost any kind of indicator mounted on the tool block and contacting the surface of the face plate as it is revolved slowly. Setting the cross slide of the lathe at right angles to the spindle, a light cut is taken across the face of the plate which ensures its being square, at least until it is removed and replaced. Where the work to be clamped on the face plate extends across the center of the plate, some prefer to have the face

of the plate very slightly concave instead of absolutely straight across. They feel that the work then bears on each side of the center and avoids all tendency to rock, as is the case if the plate is even slightly convex. If, however, care is taken to avoid any convexity, there is no need of having it concave.

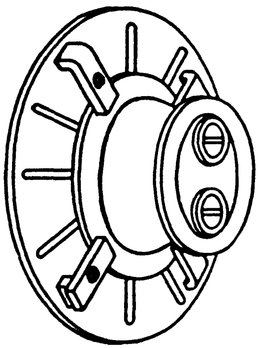


FIG. 63.—Work clamped to face plate for boring.

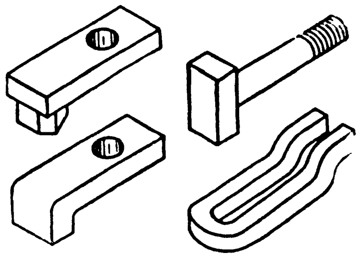


FIG. 64.—Clamps and bolt for face-plate work.

Face-plate work allows opportunity for great ingenuity on the part of the lathe operator, especially when the work is of odd or unusual shape. For plain work like the bell-shaped casting illustrated in Fig. 63, the work is held on the face plate by clamps as shown. Here the clamps bear against the flange of the casting and hold the work firmly in place. In such work it is convenient to have clamps with one end bent, as shown on some of the clamps in Fig. 64. Some shops have rings marked on the face plates every half inch to make it easy to center work of this kind. In fact, in some cases the work can be clamped to the face plate while it is on the bench and the face

plate put on the lathe with the work in place. When this is done, it is very necessary to be sure that no particle of dirt or chips get between the flanges on the spindle and the face plate. Work of this kind can be done more advantageously on a vertical boring mill than in the lathe as here the face plate is horizontal, and it is very easy to place the work on it and locate it in the proper position. Where a small vertical boring mill can be obtained, it is a valuable addition to the equipment of any small shop.

After turning the larger flange on the outer end of the piece, it is desired to turn the small bosses shown on the end. It is then necessary to move the casting across the face plate until one of the openings is central with the lathe spindle. One common method of doing this is to mark the center of the hole on a small piece of wood shown across the holes and then center this with an indicator or in any other manner. When this is centered so that the hole and flange will be at the right distance from the other boss, the work is clamped tight enough for the machining of the boss, both inside and out.

Moving the casting across the face plate has thrown the whole casting off center and made the work very much out of balance when it is revolved. This would cause vibration so that the work would not be accurate and also might damage the lathe itself. So in cases of this kind, it is necessary to fasten counterweights on the face plate, opposite the offset of the work, until the lathe runs without vibration. Work of this kind would also be done more easily on the vertical boring mill; even here the

weight on the table, or face plate, would have to be correctly balanced if it is to run at the proper speed.

When one boss is finished, the operation must be repeated by shifting the casting across the face plate until the other boss is in the right position to turn and bore. The same counterweight can be used, but it must be moved to the opposite side of the face plate.

Face plates are also sometimes used as substitutes for chucks, as in Fig. 65. Here angle pieces are bolted to the face plate with the ends bent at the right diameter to hold the work to be done. In this case the work was a plain ring which was too large to be held in the largest chuck. As this was a light finishing job it was not necessary to clamp the work tightly, and each jaw was faced on the inside with a wooden block, *B*. After they were in place, these wooden jaws were bored out so as to be a drive fit for the ring that was to be machined. It was then necessary only to tap the ring into position by very light blows until it seated against the clamps and the work was ready to bore. Positive means of holding the work could have been devised had it been necessary.

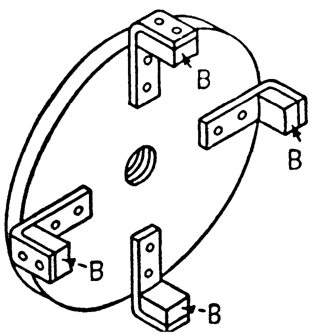


FIG. 65.—Face plate with temporary jaws.

Many face-plate jobs require the use of angle plates on which to clamp the work. Here the angle

of the work decides the angle of the plates to be used in holding it. These plates must hold the work so that the end nearest the tools will run true and be held at the proper angle for machining.

A V Block Helps to Center Work.—A three-jawed independent chuck is convenient in recentering

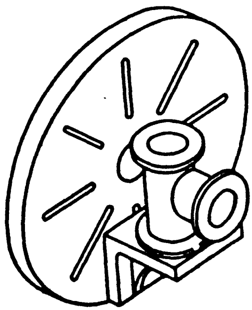


FIG. 66.—A flanged pipe "T" held on a 90-deg. angle plate for boring and facing.

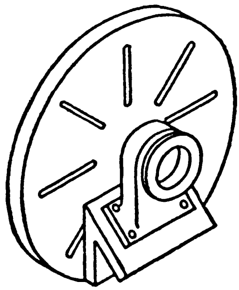


FIG. 67.—An angular face on the casting requires an angle plate with a similar angle.

round work or in making several pieces alike, when a draw-in collet of the right size is not available. For all round work in a job shop, however, a four-jawed independent chuck handles a large variety of work, especially when it is irregular in shape.

Michael Axler had to turn and bore a number of pieces of pipe within close limits and so used a V block in a four-jawed independent chuck as shown. With the aid of a V block, one accurate setup was sufficient to locate all succeeding work. With the V block securely gripped by three of the jaws, the fourth jaw was the only one used to grip and release the work. As long as the diameters of all

pieces are the same, they will all match the initial setting (see Fig. 68).

The idea should be particularly good for holding a circular piece eccentric in the chuck on a small-lot basis.

A Special Angle Plate.—A good example of a special angle plate for use in the engine lathe is seen in Fig. 69. This plate was made to be held in a four-jawed chuck, being clamped in place by the jaws themselves. The same angle plate could have been bolted to a face plate, but it was easier to locate it properly by using the chuck as shown.

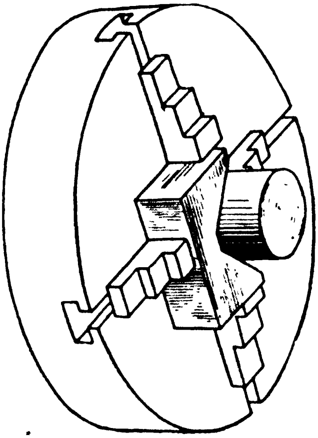


FIG. 68.—Using a V block with a four-jawed chuck.

The work is clamped by the two bolts shown, between the long jaw at the bottom and the movable clamp that is held by the bolts. With the work in place the upper jaw would be used against the nuts on the upper ends of the bolts. With the jaws made to fit the work, all sorts of odd-shaped pieces of work can be quickly located in the jaws and clamped securely for any machining that may be necessary. In this case the large cone center seen at the left aids in locating the work in the chuck. Many castings or forgings of unusual shape can be chucked easily and quickly by some such chuck as the one shown. The large cone center at

the left indicates that the outer end of the work is supported both in chucking and while being machined.

In some cases angle-plate work cannot be held as firmly as might be desired by the usual clamping methods. Where it is not necessary for the lathe

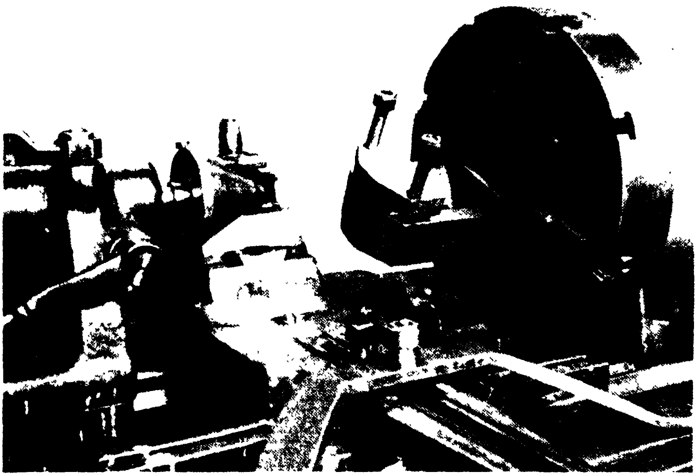


FIG. 69.—Special angle plate held in a sturdy four-jawed chuck.

tool to reach the center of the work, as in Fig. 70, it is possible to use a support against the center as shown. This prevents the work from being pulled away from the face plate and is very helpful in cases that would otherwise be difficult.

Turning Tapers.—Many lathe-work jobs call for turning tapers either the whole length or for a part of the work. If the lathe has a taper attachment, this work is comparatively easy. Remember that the tool must be at the center of the work, in height, if the correct taper is to be secured.

Where the taper must be turned by setting over the tailstock, there are several points to watch carefully. The setover of the tail center must be based on turning the taper the whole length of the work, whether this is to be done or not. For this condition the tail center must be set over one-half the amount of the taper, as in Fig. 71, to turn the piece shown. If the taper is to be turned on only half the piece, the setover must be twice as much, or equal to the taper wanted (see Figs. 72 and 75). If the taper is only one-quarter of the length, as in Fig. 73, the tail center must be set over four times as much. It does not matter where the taper is located, whether at the end as in Fig. 72 or near the center as in Fig. 73. The setover is the same. A little figuring will show why.

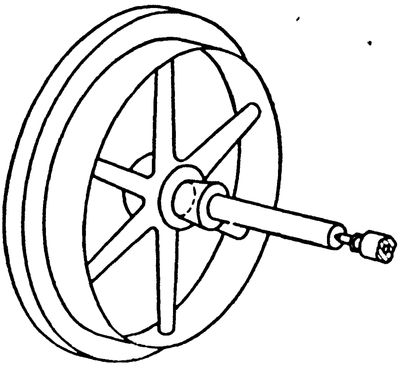


FIG. 70.—Centering and holding pulleys against a face plate.

In the first case, with the taper running the whole length, the finished piece will be 3 in. in diameter at the small end and 5 in. at the large end, a difference of 2 in. In this case the setover is half this difference, or 1 in. (see Fig. 74).

With the taper extending only half the length, as in Fig. 72, the diameter at the large end, if the taper extended the whole length, would be 7 in., a differ-

ence of 4 in., so the setover must be 2 in. in this case.

Having the taper extend only one-quarter the length, as in Fig. 73, would make the small end only 1 in. in diameter, if extended, and the large end 9 in., a difference of 8 in. This means that the

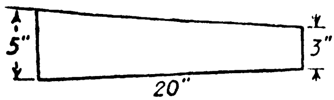


FIG. 71.

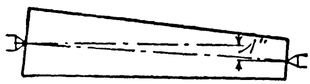


FIG. 74.

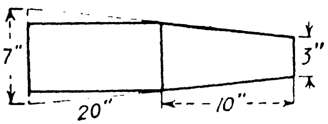


FIG. 72.

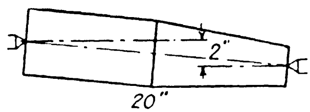


FIG. 75.

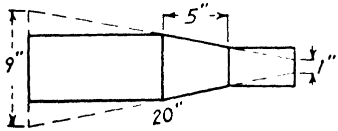


FIG. 73.

Location of Tapers

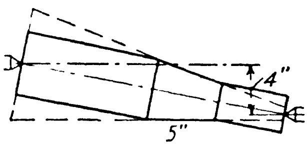


FIG. 76.

Setover in Lathe

FIGS. 71 to 76.—Tapers and Setover in Lathe.

setover must be half of 8, or 4 in. The setover is shown in Fig. 76.

In turning tapers in this way it is well to remember that it is seldom that we get just the desired taper at the first trial. The depth of the center hole in the piece of work affects the taper to some extent. Neither is it always possible to get the cutting point of the tool at the exact center height of the work.

Both of these things affect the resulting taper. It is usually safer to set the tail center over a little more than you think it should be and have the trial cut a little more taper than you want for the finished piece.

You can begin to test the taper before the small end gets down near the size of the finished piece and

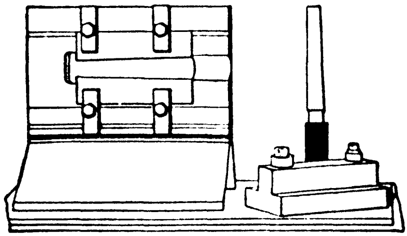


FIG. 77.—An accurate taper gage.

make corrections after a few cuts. The taper can be checked by measuring the diameter at two points, a known distance apart, and checking the taper in that distance. If the tapered bar is to fit a tapered hole, be sure of the taper of the hole. If it is a reamed hole, check the taper by the reamer. If it is a bored hole, the situation is a little more complicated. It may be possible to check the taper by the hole itself before the final cuts are taken. A little chalk rubbed on the bar will show the points at which it bears.

If it is a very important fit, it will pay to make a gage that fits the hole and make the bar to suit this gage. Such a gage can be made of sheet metal and fitted until it bears at the large and small ends. Or disks of known diameter can be put on a threaded

rod and adjusted until they both contact the tapered hole. Knowing their diameters and measuring the distance of the disks from each other, you can duplicate this on the work being turned and be sure that it is right. If there is much taper work to be done, it will pay to rig up a taper gage as shown in

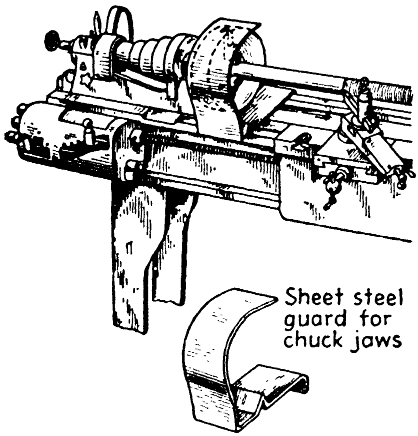


FIG. 78.—Chuck guard that is easily removed.

Fig. 77. This is a U-shaped plate on a suitable stand, with two straightedges clamped one on each side of the U opening. Setting these straightedges to a standard plug, or by measurement, gives a gage that is accurate and easy to use. Light will show between the gage and the work with a very slight variation from a true contact all along the surface.

A Homemade Chuck Guard.—Gearing is now guarded very well on most lathes built within the past quarter century, but chuck jaws still present a hazard on many fast-running lathes. One shop made several chuck guards like those in Fig. 78,

which can be easily taken off and used on any lathe of similar size.

Fairly heavy sheet steel is used so that it will retain its shape and not sag to make contact with the chuck when in place. The lower part fits over the ways of the lathe, and if it can hook under the back of the bed, it is more apt to stay in place, particularly if there is any vibration or jarring of the lathe during the cut. The width should be enough to cover the chuck jaws when the guard is pushed up against the headstock. It should clear the chuck jaws by a good half inch. The guard can be slid away from the headstock while the work is being chucked and then moved back into place when work starts. This is usually as convenient as the kind of guard where the top swings back for chucking.

Turning Profiles on a Lathe.—Profile turning can be done on any engine lathe if you have enough work of this kind to make it worth while, nor is the setup at all expensive, as can be seen from Fig. 79, which shows how it was done on an Atlas lathe. It can also be done on a lathe without the taper attachment shown.

A template of the correct size and shape is fastened to the back of the lathe. If it has a taper attachment as shown, this is a good place to fasten it. On the arm connecting the carriage with the taper attachment is fastened a follower, as shown, having the contact point of the follower the same shape as the cutting tool, if an accurate copy of the form is required.

Remove the nut from the cross slide so that the

cross movement can be controlled by the stiff springs that are fastened to the back of the lathe carriage. These springs hold the contact point or follower against the form at the back and move the tool in

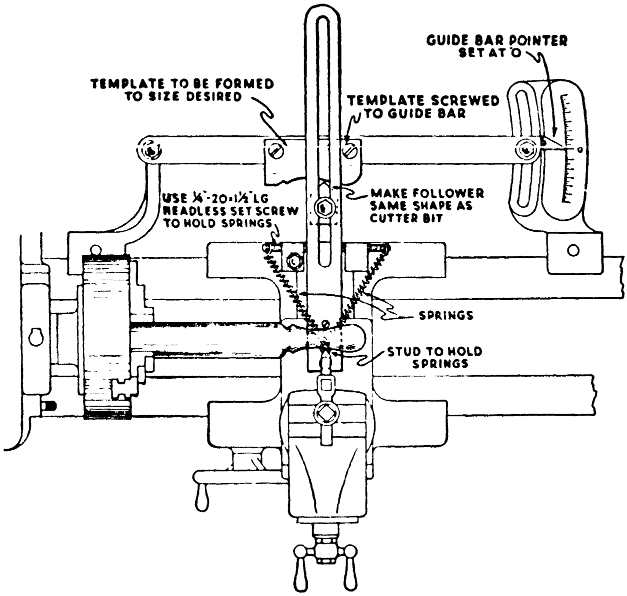


FIG. 79.—A method of turning profiles on an engine lathe.

and out as the carriage moves along the bed, and the follower keeps in contact with the follower at the back. If there is a taper attachment, it should be set at zero, as shown in Fig. 79. It would seldom be advisable to turn a handle, or other work, with a long length projecting from the chuck. It should be supported by the tail center or by a steady rest between the formed handle and the chuck. The shape of the handle being turned could be varied

to some degree by moving the taper attachment bar at the back. Moving it back would make the end of the handle somewhat larger; moving it forward would decrease the end diameter.

Lathe, Shaper, and Planer Tools.—For many kinds of work the same tools can be used in the lathe, the shaper, and the planer. They are all single-point tools except for special work, and although some of them vary from the others, depending on the exact operation, they are very similar. In the old days each tool was forged from a bar of steel of the proper size, and a variety of tools required tying up a lot of tool steel in the shanks as well as in the cutting edges. Now, except in very large and heavy work, toolholders are used and the cutting tools, or "bits," are comparatively small pieces of high-speed steel. By having a few toolholders of different shapes, all regular machining operations on the lathe, shaper, and planer can be done with the same tools. An idea of the old tools and the new can be had from Figs. 80 and 81.

The shapes of the cutting points have also changed with the years. Instead of the diamond-point tool, which was the one most used in the old days, we now use round-nosed tools for all roughing work. They last longer without dulling, and there is much less breakage. This change has been made possible partly by the increased power now used in lathes and other machine tools. Instead of a 2-in. belt driving a 16-in. lathe, as in the old carbon-tool days, we now use motors with from 5 to 25 hp. on the same-sized lathe. If you have an old belt-

driven lathe that will not pull a heavy cut, try using a side, or facing, tool instead of a round-nosed or

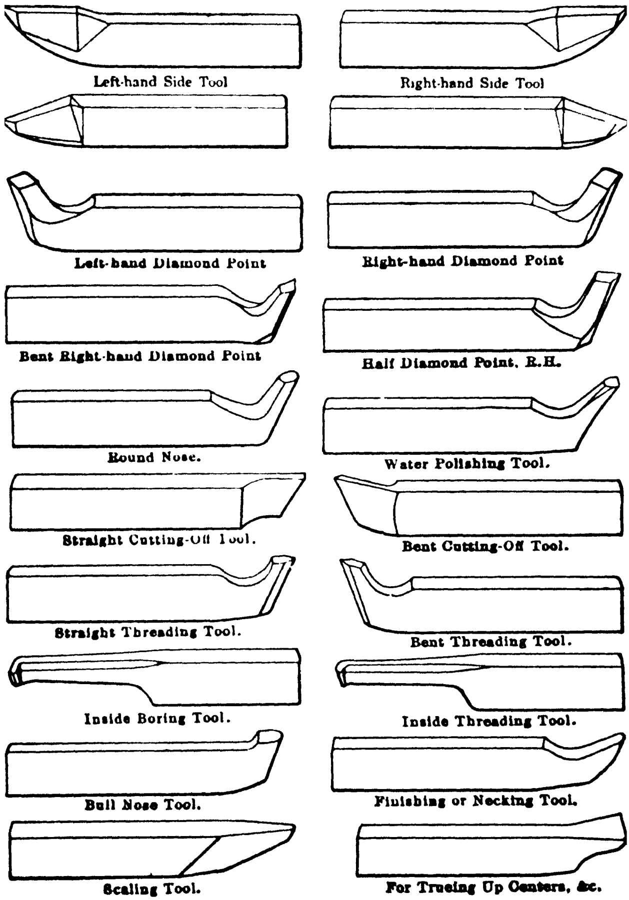


FIG. 80—A collection of old forged tools.

even a diamond-point. This tool acts more as a shearing tool and removes metal with less power

than the others. It may get dull more quickly, but it may also help out on a job that could not be done with the regular type of tool.

It pays to have a fair-sized supply of tool bits on hand and to be sure that enough of them are kept

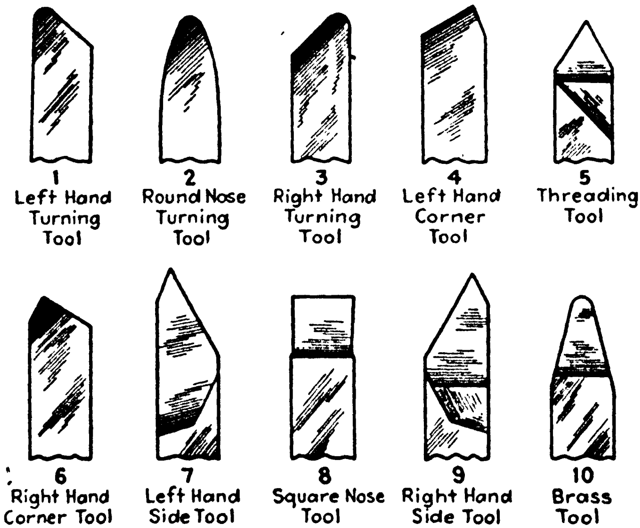


FIG. 81.—Ten types of bits for modern toolholders.

sharp so as not to delay the work. One of the secrets of getting work out on time is to have the tools and materials ready when needed. Bits for standard toolholders are shown in Fig. 81.

Boring Small Holes with a Tailstock Tool.—Although normal boring work in an engine lathe is done with the boring tool fastened in the tool post on the cross slide, it sometimes happens that it is better to keep the cross slide for cutting off work

and so save changing tools. Figure 82 shows a way in which a number of small holes were bored with a tool held in the tailstock, leaving the cross slide free for the cutting off of the work.

The boring tool has a shank that is held in a drill chuck in the tailstock of the lathe. The boring tool itself is pivoted in an enlarged portion of the tool as shown, and has two adjusting screws that bear against the tool, as indicated. By loosening one of

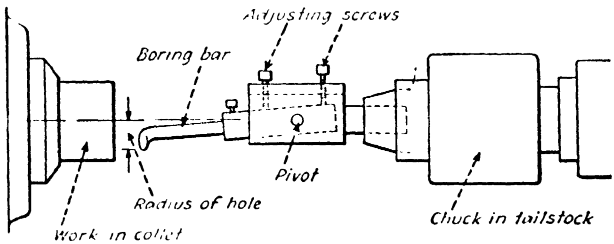


FIG. 82.—Boring tool for small holes.

these screws and tightening the other, the point of the tool can be adjusted by very small amounts to give the desired depth of cut in the work. The boring tool itself is held in the holder shown in the pivoting head. This has been found very useful in some small work and is more convenient than the tool post for such small work.

Winding Springs in a Lathe.—It is often necessary to wind a special spring to fit into some repair job. The lathe is the natural place for this work. The requirements are that one end of the wire be held firmly in or on the mandrel on which it is to be wound, and that sufficient tension be put on the wire to make it follow the contour of the rod or

mandrel. It is first necessary to find out how much the wire being used will spring back when the tension is released and so increase the diameter of the spring. This is important where the spring must fit into a recess or where space is limited in any way. A sample turn or two will give this information. If

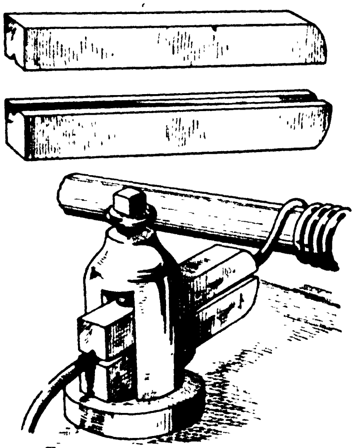


FIG. 83.—Winding a spring in the lathe.

the resulting spring is too large, a smaller rod or mandrel must be used.

It is frequently possible to clamp the end of the wire in the chuck that carries the mandrel, but it is usually easier to drill a hole in the mandrel to hold the end while the spring is being wound. This secures the wire and leaves the method of applying tension to be decided. Figure 83 shows a simple method of applying tension by using two pieces of steel or wood in the tool post of the lathe. As the pieces have a groove that is a little smaller than the

wire, it must be pulled through the block as the lathe turns.

The other method, shown in Fig. 84, does not require the use of the tool post, but the wire-holding device may require a little more work. It consists of a block of wood with a V cut in the end to go against the mandrel, and one or more holes through which the wire is fed. A handle enables the piece

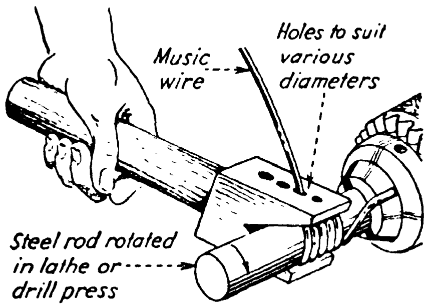


Fig. 84.—Another way of winding springs in a lathe.

to be held in the hand and fed along as the spring is wound. The illustration shows the end of the wire fastened between the jaws of the chuck.

If the spring is to be close wound, *i.e.*, with the coils in contact, as for a spring in tension, it is easy to feed the wire by keeping contact with the preceding coil. For a compression spring the coils must be separated. This can be done by using the lead screw of the lathe with the gearing of the right pitch, or a spacer between the coils.

CHAPTER VIII

MILLING MACHINE WORK

Milling machines are very convenient and economical tools for the small shop, but many such shops start work without one. A hand miller will take care of a large variety of work, but it is a machine for small manufacturing rather than for the job shop, as its scope is more limited than the standard or universal milling machine. It is of course much cheaper to buy and will be found very useful in any shop. But if it is possible to get hold of a universal miller, even of fairly ancient vintage, it will prove very versatile if it is in fair condition. Of course, the bearings must be tight and the feed screws free from backlash. But with these in working order, a universal miller will do almost anything from making a special twist drill to cutting helical gears, not to mention numerous plain milling jobs of all kinds.

Milling cutters, especially those of modern design with carbide-tipped teeth, cost money. But the small shop can get by with carbon or high-speed cutters until it grows to carbide proportions. A few plain cutters for milling flat surfaces, cutting keyways, and side milling, and a few cutters for the common sizes of Woodruff keys will handle quite a

variety of work in any small shop. Keyways and other slots can also be cut with end mills, which will be found useful in many ways.

With any kind of cutter it is better to keep it cutting than to let it slide over the work with a sort of scraping cut. There should be a definite depth of cut, from 0.002 to 0.006 in. per tooth. This will prevent the cutter from being dulled by merely scraping over the metal. It is important in all milling to keep the cutters sharp and to be sure that each tooth is doing its share of the work. This requires careful grinding, using a tooth rest and checking the cutters with a dial gage, to be sure that each tooth is doing its share of the work. This saves cutters and gets out work faster.

Milling Jobs.—Just to give some idea of the many ways in which a milling machine can be used for different kinds of work, the sketches from Fig. 85 to Fig. 88 are given. They show nearly all kinds of common cutters in use, including plain slabbing cutters, end mills, face mills, T-slot cutters, dovetail cutters, form cutters, and gear cutters. At *A*, *B*, and *C* in Fig. 85 is shown the same job being done in two operations and with a single pass by using a gang of cutters. Another is shown at *D*.

Figures 86 and 87 show types of work that need no explanation. Although some of these can be done on a hand miller, they can all be done on either a plain or universal miller of standard type. The universal machine is suggested because of the greater variety of work it can do, as shown in Figs. 89 and 90. Both of these make use of the indexing

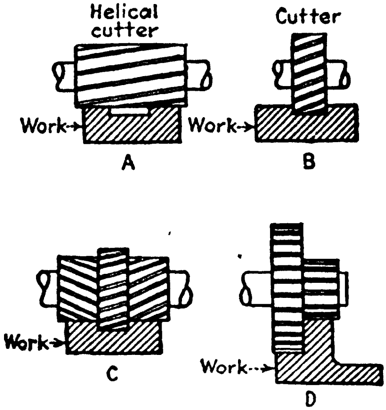


FIG. 85.—Simple milling with single or gang cutters.

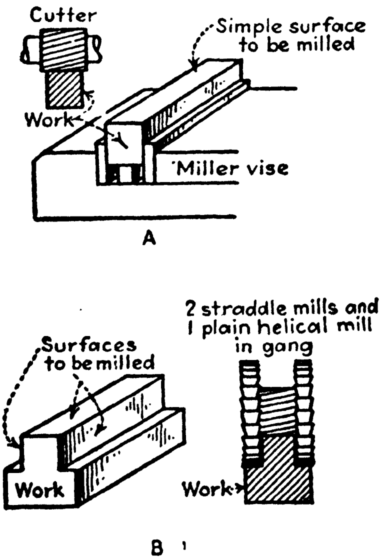


FIG. 86.—Two simple milling jobs.

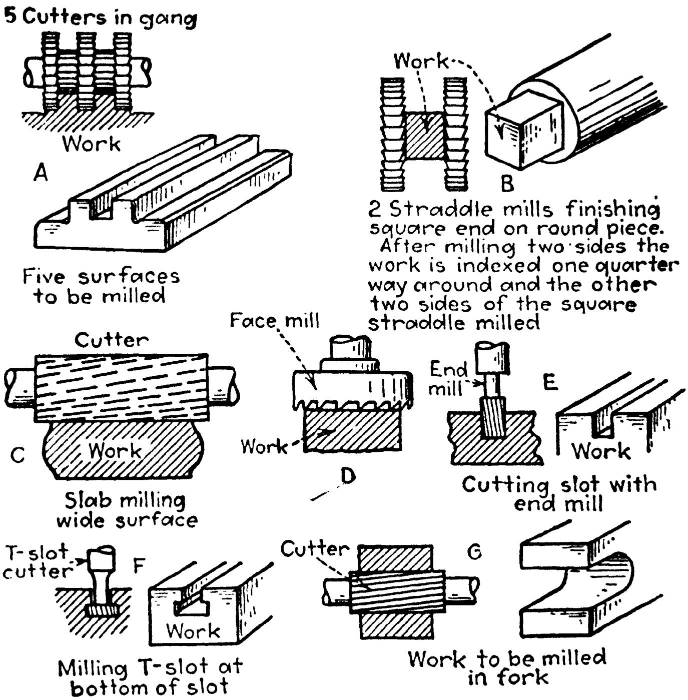


FIG. 87.—Several typical milling jobs.

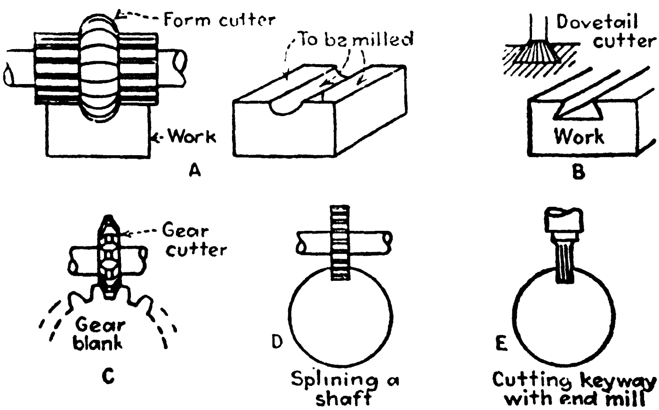


FIG. 88.—Half-round, dovetail, and other slots.

head, which greatly broadens the scope of the machine.

Where a number of pieces are to be made alike,

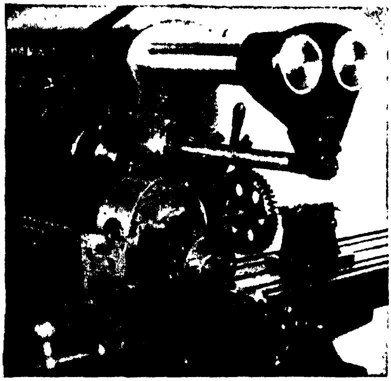


FIG. 89.—Gashing a worm wheel.

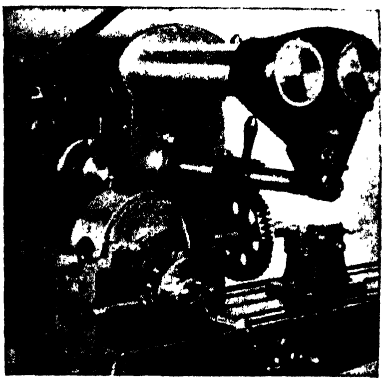


FIG. 90.—Hobbing a worm wheel.

it often pays to make a simple fixture, as illustrated in Fig. 91. This shows some bearing caps milled almost continuously, by having two fixtures so that one can be loaded while the other is being milled.

When fixtures are not available, it is possible to hold a large variety of work by using standard blocking and clamps, such as are shown in Fig. 92. The first nine are standard forged clamps, which can be bought easily. The step block *J* is very con-

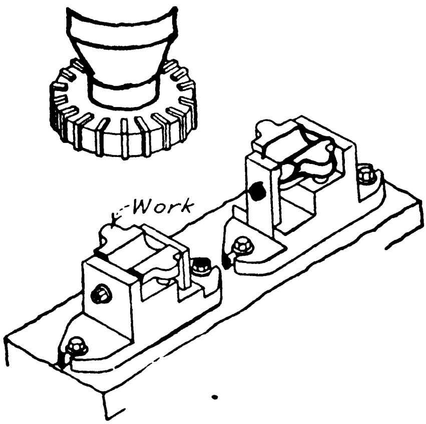


FIG. 91.—Double fixture to secure continuous milling.

venient because you can select the height nearest that of the work. If none of them come level with the work, use the next step higher rather than the lower one, as this gives a better position to the clamp. The bolt *K*, the wedge *M*, and the two screw jacks are also convenient in many places.

Power at the Spindle. In these days of electric motors there are comparatively few belt-driven machine tools. But the smaller shops are likely to have one or more machines with belt drives, and it is advisable to have some idea as to the power transmitted by them. Roughly speaking, a good single-thickness belt is rated to transmit 1 hp. at 600

f.p.m., for each inch of width. A double belt is rated at 1½ hp. at the same speed. This allows for ordinary slippage with belts and pulleys in good condition.

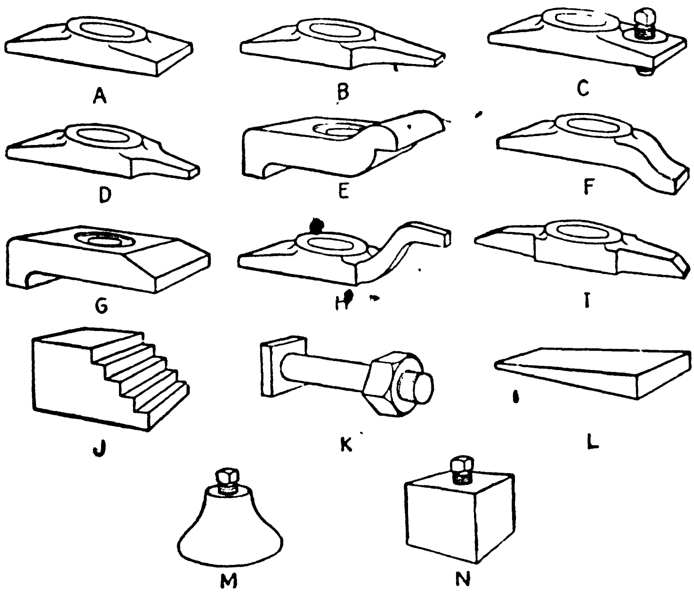


FIG. 92.—Clamps, blocks, bolt and screw jacks suggested by Brown and Sharpe.

To calculate the belt speed you must know the diameter of the pulley and the speed at which it runs. Assume a pulley to be 12 in. in diameter and running at 1,000 r.p.m. The distance around its rim is 3⅐ times the diameter. To be more exact, you can use 3.1416 as a multiplier, but 3⅐ is good enough. In fact, for rough calculations you can drop the fraction and so have a little wider margin

of safety. Calling it $3\frac{1}{7}$, the circumference of a 12-in. pulley is $37\frac{5}{7}$ in. Dropping the fraction entirely you can call it 36 in. At 1,000 r.p.m. it makes 36,000 in. per minute belt speed. Dividing by 12 gives 3,000 ft. per minute. Dividing 3,000 by 600 gives 5 hp. per inch of width for a single belt. For a double belt multiply 5 by $1\frac{1}{2}$, which gives $7\frac{1}{2}$ hp.

But since 1,000 r.p.m. is rather fast for most pulleys, let us call the speed 750 r.p.m. and the pulley 10 in. in diameter. Ten times $3\frac{1}{7}$ gives $31\frac{3}{7}$ in. as the circumference. Dropping the fraction again, we have 31 times 750 or 23,250 in. per minute. Dividing by 12 gives 1,937 ft. per minute, and dividing by 600 gives 3.22 hp. per inch of width for single belts, or 4.83 hp. when we add 50 per cent for a double belt. With a 4-in. belt we have 12.88 hp. for a single and 19.32 hp. for a double belt.

This allows 25 per cent of the power put into the machine to be absorbed by the bearings and the gearing. Although this allowance may be high for machines in good condition, it is probably a safe average. It is better to have more power than to have less than you figured on, at the cutter.

It will also be useful at times to know the power available in calculating the feed that can be used in milling if you are to take advantage of the newer milling cutters, either high-speed or carbide. Although the small shop will have but few carbide cutters, as their cost is seldom warranted unless they can be used on long runs, it is well to know what speeds and feeds can be used if the job makes it profitable.

CHAPTER X

CUTTING SPEEDS

Cutting speeds in either turning or milling depend on the size of the work being turned or of the milling cutter in use. The number of revolutions of the machine is usually indicated on all modern machines, which makes it necessary to consider only the work or the cutter.

Instead of taking time to figure out the speed necessary to give the cutting speed desired for each job it is much easier to consult a table such as Table 9. If, for example, the work is 3¼ in. in diameter and you want to cut it at 50 ft. per minute, it is only necessary to find 3¼ in the first column and follow across the table to the column marked 50, which shows that the work must turn 58.8 r.p.m. for this cutting speed.

There will, of course, be no such speed in the table on the machine, so you will pick the nearest speed—probably 60. If you want 90 ft. a minute cutting speed, you use the 30 column and multiply by 3 or the 45 column and multiply by 2. In the same way, if the work is 22 in. in diameter, you use 11 in. in the first column and divide the speed shown by 2. In this way you can get ranges of speeds far beyond the table.

With milling cutters, use the first column as the

TABLE 8.—SPEED CHART, MILWAUKEE MILLING MACHINES NOS. 1 AND 2

Chart must be used carefully. Start slowly and work up.
Learn what cutters will stand. Start with slow feed and step up.

Material to be milled	Material in Cutter					
	Carbon tool steel	High-speed steel	Super-high-speed steel	Stellite	Tantalum carbide	Tungsten carbide
	Cutter speed, ft. per minute					
Aluminum	250–500	500–1,000	. . .	800–1,500	. . .	1,000–2,000
Brass, soft	40–80	70–175	.	150–250	. . . .	350–600
Bronze, hard	30–60	65–130		100–160	. . . .	200–425
Bronze, very hard	. . . .	30–50	50–70	. . . .	. . . .	125–200
Cast iron, soft	30–40	50–80	60–115	90–130	. . . .	250–325
Cast iron, hard	. . . .	30–50	40–70	60–90	. . . .	150–200
Cast iron, chilled	. . . .	. .	30–50	40–60	. . . .	100–200
Malleable iron	35–50	70–100	80–125	115–150	. . . .	250–370
Steel, soft	30–45	60–90	70–100	. . . .	150–250	
Steel, medium	30–40	50–80	60–90	. . . .	125–200	
Steel, hard	. . . .	30–50	40–70	. . . .	100–150	

TABLE 9.—CUTTING SPEEDS

Ft. per minute	15	17.5	20	22.5	25	27.5	30	35	40	45	50	55
Diam.	Revolutions per minute											
1/16	917	1,070	1,222	1,375	1,528	1,681	1,833	2,139	2,445	2,750	3,056	3,361
1/8	458	535	611	688	764	840	917	1,070	1,222	1,375	1,528	1,681
3/16	306	357	407	458	509	560	611	713	815	917	1,019	1,120
1/4	229	267	306	344	382	420	458	535	611	688	764	840
5/16	183	214	244	275	306	336	367	428	489	550	611	672
3/8	153	178	204	229	255	280	306	357	407	458	509	560
7/16	131	153	175	196	218	240	262	306	349	393	437	480
1/2	115	134	153	172	191	210	229	267	306	344	382	420
5/8	91.7	107	122	138	153	168	183	214	244	275	306	336
3/4	76.4	89.1	102	115	127	140	153	178	204	229	255	280
7/8	65.5	76.4	87.3	98.2	109	120	131	153	175	196	218	240
1	57.3	66.8	76.4	85.9	95.5	105	115	134	153	172	191	210
1 1/8	50.9	59.4	67.9	76.4	84.9	93.4	102	119	136	153	170	187
1 1/4	45.8	53.5	61.1	68.8	76.4	84.0	91.7	107	122	138	153	168
1 3/8	41.7	48.6	55.6	62.5	69.5	76.4	83.3	97.2	111	125	139	153
1 1/2	38.2	44.6	50.9	57.3	63.7	70.0	76.4	89.1	102	115	127	140
1 5/8	35.3	41.1	47.0	52.9	58.8	64.6	70.5	82.3	94.0	106	118	129
1 3/4	32.7	38.2	43.7	49.1	54.6	60.0	65.5	76.4	87.3	98.2	109	120
1 7/8	30.6	35.7	40.7	45.8	50.9	56.0	61.1	71.3	81.5	91.7	102	112
2	28.7	33.4	38.2	43.0	47.7	52.5	57.3	66.8	76.4	85.9	95.5	105

2¼	25.5	29.7	34.0	38.2	42.4	46.7	50.9	59.4	67.9	76.4	84.9	93.0
2½	22.9	26.7	30.6	34.4	38.2	42.0	45.8	53.5	61.1	68.8	76.4	84.4
2¾	20.8	24.3	27.8	31.3	34.7	38.2	41.7	48.6	55.6	62.5	69.5	76.4
3	19.1	22.3	25.5	28.6	31.8	35.0	38.2	44.6	50.9	57.3	63.7	70.0
3¼	17.6	20.6	23.5	26.4	29.4	32.3	35.3	41.1	47.0	52.9	58.8	64.6
3½	16.4	19.1	21.8	24.5	27.3	30.0	32.7	38.2	43.7	49.1	54.6	60.0
3¾	15.3	17.8	20.4	22.9	25.5	28.0	30.6	35.7	40.7	45.8	50.9	56.0
4	14.3	16.7	19.1	21.5	23.9	26.3	28.7	33.4	38.2	43.0	47.7	52.5
4½	12.7	14.9	17.0	19.1	21.2	23.3	25.5	29.7	34.0	38.2	42.4	46.7
5	11.5	13.4	15.3	17.2	19.1	21.0	22.9	26.7	30.6	34.4	38.2	42.0
5½	10.4	12.2	13.9	15.6	17.4	19.1	20.8	24.3	27.8	31.3	34.7	38.2
6	9.5	11.1	12.7	14.3	15.9	17.5	19.1	22.3	25.5	28.6	31.8	35.0
6½	8.8	10.3	11.8	13.2	14.7	16.2	17.6	20.6	23.5	26.4	29.4	32.3
7	8.2	9.5	10.9	12.3	13.6	15.0	16.4	19.1	21.8	24.5	27.3	30.0
7½	7.6	8.9	10.2	11.5	12.7	14.0	15.3	17.8	20.4	22.9	25.5	28.0
8	7.2	8.4	9.5	10.7	11.9	13.1	14.3	16.7	19.1	21.5	23.9	26.3
8½	6.7	7.9	9.0	10.1	11.2	12.4	13.5	15.7	18.0	20.2	22.5	24.7
9	6.4	7.4	8.5	9.5	10.6	11.7	12.7	14.9	17.0	19.1	21.2	23.3
9½	6.0	7.0	8.0	9.1	10.1	11.1	12.1	14.1	16.1	18.1	20.1	22.1
10	5.7	6.7	7.6	8.6	9.5	10.5	11.5	13.4	15.3	17.2	19.1	21.0
11	5.2	6.1	6.9	7.8	8.7	9.5	10.4	12.2	13.9	15.6	17.4	16.1
12	4.8	5.6	6.4	7.2	8.0	8.8	9.5	11.1	12.7	14.3	15.9	17.5
13	4.4	5.1	5.9	6.6	7.3	8.1	8.8	10.3	11.8	13.2	14.7	19.2
14	4.1	4.8	5.5	6.1	6.8	7.5	8.2	9.5	10.9	12.3	13.6	15.0
15	3.8	4.5	5.1	5.7	6.4	7.0	7.6	8.9	10.2	11.5	12.7	14.0
16	3.6	4.2	4.8	5.4	6.0	6.6	7.2	8.4	9.5	10.7	11.9	13.1
17	3.4	3.9	4.5	5.1	5.6	6.2	6.7	7.9	9.0	10.1	11.2	12.4
18	3.2	3.7	4.2	4.8	5.3	5.8	6.4	7.4	8.5	9.5	10.6	1.17

TABLE 10.—CUTTING-FLUIDS SELECTION GUIDE

These recommendations were prepared by the Headquarters Wage Incentives Department, Westinghouse Electric Corporation

Cutting Fluids for Machine Reaming

Material	Cutting fluid
Aluminum and alloys Magnesium and alloys	Mineral lard oil Kerosene Soda water
Brass and bronze	Soda water
Cast iron	Dry
Cast steel	ard oil Mineral lard oil Soda water
Copper	Lard oil Soda water
Malleable iron	Soda water Mineral lard oil
Monel metal	Lard oil Soda water
Mild steel	Mineral lard oil Soda water
Tough alloy steels Steel forgings	Mineral lard oil Sulphurized oil Soda water
Steel, tool	Lard oil Sulphurized oil Soda water
Wrought iron	Mineral lard oil Soda water
Micarta and Bakelite	Mineral lard oil

Cutting Fluids for Tapping

Material	Cutting compound
Aluminum alloys	½ lard oil and ½ kerosene
Magnesium alloys	Light mineral oil
Brass and bronze	Light mineral oil Dry
Cast iron	Small amounts of mineral lard oil, soap, or tallow
Copper	Cresol z-3* and paraffin oil No. 3313-4 and paraffin oil
Malleable iron	Sulphurized oil
Monel metal	Lard oil and kerosene Sulphurized oil
Wrought iron Mild steel	No. 3313-4 and paraffin oil
Tool steel	Sulphurized oil Lard oil and kerosene
Stainless steel	Sulphurized oil
Tough alloy steels Cast steel Steel forgings	Sulphurized oil
Rubber, hard Fiber	Dry
Micarta, moldarta and other molded plastics	Dry

* **Cresol z-3 is an excellent heat dissipator and does not stain the work. It is rather expensive but may be used in a 10 per cent solution of paraffin oil. No 3313-4 is also sulphurized oil.**

TABLE 10.—CUTTING-FLUIDS SELECTION GUIDE—(*Continued*)

Cutting Fluids for Drilling

Material	Cutting Fluid	
	Order of decreasing effectiveness	Order of increasing expense
Aluminum and alloys	Kerosene Kerosene and lard oil Soda water	Soda water Kerosene Kerosene an lard oil
Brass	Dry Kerosene and mineral lard oil } Deep holes Soda water } Deep holes	Dry Soda water Kerosene and mineral lard oil
Magnesium and alloys Bronze	Mineral lard oil Soda water Dry	Dry Soda water Mineral lard oil
Copper	Mineral lard oil and kerosene Soda water Dry	Dry Soda water Mineral lard oil and kerosene
Monel metal Mild steels Tough alloy steels Steel forgings Cast steel Wrought iron	Mineral lard oil Sulphurized oil Soda water	Soda water Mineral lard oil Sulphurized oil
Manganese steel Cast iron	Dry	Dry
Malleable iron	Dry Soda water (deep holes)	Dry Soda water
Tool steel	Mineral lard oil and kerosene Kerosene Mineral lard oil	Mineral lard oil Mineral lard oil and kerosene Kerosene
Micarta, Bakelite fiber, asbestos, hard rubber, ebony	Dry	Dry

diameter of the cutter instead of the work, as in turning. This shows that a $5\frac{1}{2}$-in. cutter will have to run 20.8 turns per minute to give a cutting speed of 30 ft. per minute, while an 8-in. cutter will run only 14.3 turns per minute for the same speed. As with the turning speeds, select the one nearest the figure given. In both cases it may be safer to select a speed below the desired figure until you are sure that the tools will stand the next higher speed.

Table 8 gives suggested speeds for smaller sizes of milling machines.

Cutting Fluids for Different Materials.—Best results in machining metals of various kinds, as well as Bakelite and other plastics, often depend on using the best coolant or lubricant, whichever you decide to call it. Perhaps the safest name is "cutting fluid," regardless of just what it does to the work. Table 10 will be found very useful for drilling, reaming, and tapping the various materials shown, which range from aluminum and magnesium to micarta and Bakelite. Some of these metals are difficult to machine, and much better results will be secured by following the advice of those with experience. In most cases the same cutting fluid used in drilling will be found suitable for turning and milling.

CHAPTER X

WATER-HARDENING TOOL STEEL

Although the use of high-speed steel and carbide tools is now very common, there are still places where water-hardening tool steel can be used to advantage. It is also probable that you will have to make special cutters and other tools, perhaps for customers if not for yourself, and the accompanying data, by the Columbia Tool Steel Co., may prove very helpful. Although you may not be interested in the analysis of the steel, an idea of its contents is given.

Eliminating Trouble in Heat-treatment of Press Tools. Most heat-treating troubles in hardening tool steel are due to cracking or distortion of the steel during the treating process. The toolmaker, by care and observation of a few fundamentals, can do much toward eliminating them.

Figure 93 shows a punch with a heavy body but a thin punch section. During the hardening of such a member, the thin section absorbs the heat of the furnace more rapidly than the heavy body. The quenching will also be detrimental, as the thin section will cool off much faster than the heavier portion and thereby set up internal stresses.

To eliminate cracking or distortion through these stresses, loose pieces of plain machine steel should be wired or bolted to the punch to prevent the heat

TABLE 11.—WATER-HARDENING TOOL-STEEL CHARACTERISTICS

Type	Grade	Analysis		Uses Water-hardening tool steel, for cold work, dies, and tools requiring	Hardening characteristics		
					Hardening temperatures	Quench	RC
Carbon alloy treated	Special	C Mn Si Cr V	* 0.25 0.25 0.15 0.04	Highest quality Keen cutting High surface hardness with a tough core	Range: 1420 to 1530°F. Cutting and shearing tools: 1420 to 1450°F. Parts subject to steady pressure: 1440 to 1480°F. Dies subject to severe blows: 1470 to 1530°F.	Water or brine	64–66
Carbon	Extra	C Mn Si	* 0.25 0.20	High hardness of medium depth Good wear resistance Shock resistance	Range: 1425 to 1550°F. Cutting and shearing tools: 1425 to 1450°F. Forming; steady pressure tools: 1440 to 1490°F. Dies subject to heavy blows: 1500 to 1550°F.	Water or brine	64–66
Carbon vanadium	Vanadium extra	C Mn Si V	0.95 0.30 0.25 0.20	Increased wear resistance Added toughness and fatigue resistance	Range 1450 to 1500°F.	Water or brine	64–66
Carbon chrome	Water die	C Mn Si Cr	1.00 0.35 0.25 0.55	Uniform strong case in large sections High wear resistance	Range 1500 to 1525°F.	Water or brine	64–66
Carbon manganese	Extra header die	C Mn Si	0.95 0.35 0.25	Uniform deep hardening in tools such as header dies	Range 1475 to 1550°F.	Water or brine	64–66

QUENCHING: A brine quench 60 to 80°F. is recommended. Remove tools from the quench at approximately 300°F. and cool in air to about 125°F. and temper immediately.

TEMPERING: These are usually tempered from 300 to 600°F. As the temperature increases, hardness decreases and toughness increases.

NOTE: These steels meet rigid hot etch and hardenability standards. Water-hardening steels harden with a depth of case of ⅛ to ¼ in. depending on mass, hardening temperature, and hardenability.

* Available in three carbon ranges: approx. C 1.15; approx. C 1.05, and approx. C 0.95.

from being absorbed too rapidly by the thin section of the punch, and also to prevent the thin section from cooling faster than the heavy body, thus overcoming the detrimental quenching action.

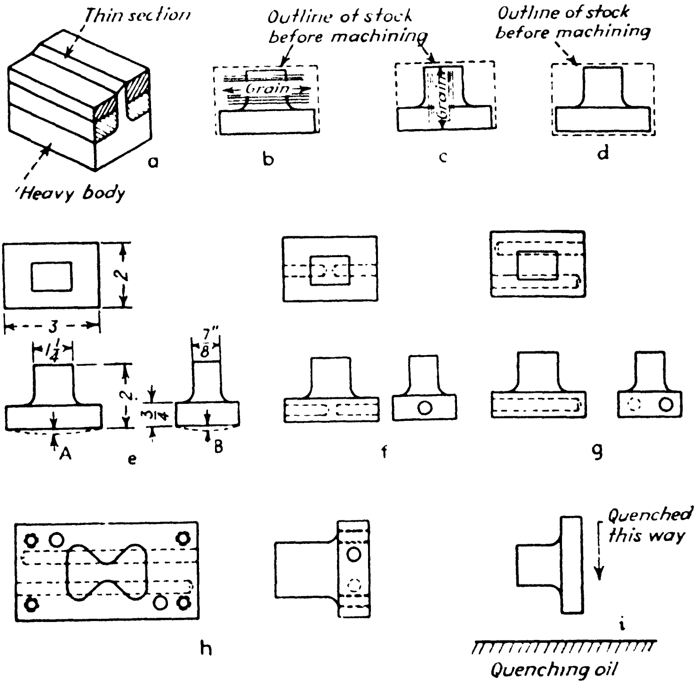


FIG. 93.—Suggestions for quenching punches and dies.

Figures 93*b* and 93*c* show by the dotted outlines blanking punches being machined from a tool-steel block. The grain of the blocks is indicated to show how the tool steel was cut from the bar stock. In order to save material, no metal was removed from the tool-steel block at the bottom of the punch, as

shown in Fig. 93*b*, and on one side of the punch, as in Fig. 93*c*. Such a practice will probably develop trouble during the heat-treating process because the outer layer of the tool steel, which was not machined off, has different hardening qualities from the steel with the outside layers removed all round. It is therefore important that these tool parts should have the decarburized outside layers removed from all sides, as in Fig. 93*d*.

Figure 93*e* shows a punch with a heavy heel which will likely bulge, as indicated by the dotted outline, when being hardened, because all corners are cooled first during the quenching process, thus setting up internal stresses through the delayed cooling of the actual center of the large heel or punch body.

In order to overcome the internal stresses, holes can be drilled into the heel of the punch, as seen in Figs. 93*f* and 93*g*. Instead of bulging the punch then, the holes are collapsed during the quenching, as recorded by W. Kassebohm and verified by the following figures from actual experience.

Type of steel:

0.85–0.90 C	1.05–1.25 Mn
0.20–0.35 Si	0.40–0.60 Cr

Slow preheat; fast heat to 1475 in muffled furnace without atmosphere but with accurate gas mixture and temperatute control.

Quenched in light oil, as shown in Fig. 93*i*.

Drawn at 400° F. Hardness Rockwell, C 61–63.

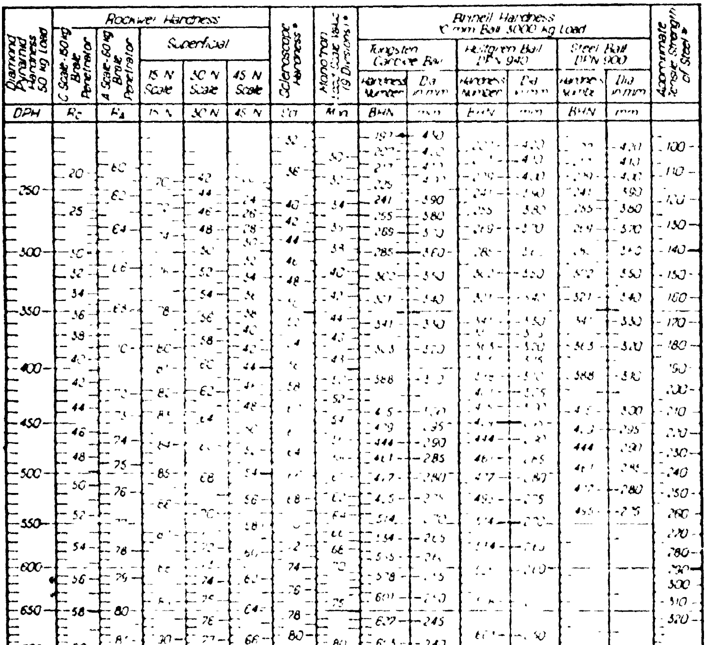
Result:

	A	*B*
Punch as per Fig. 93*e* (no stress-relief holes)	0.00025	0.003
Punch as per Fig. 93*f*	0.0002	0.0000
Punch as per Fig. 93*g*	0.0001	0.0001

The three punches had identical over-all dimensions as shown by Fig. 93*e*, and care was used in cutting the bar, machining, heat-treating, and drawing to assure identical treatment all through. As seen from these experiments, distortion of heavy-bodied tool parts, as in Figs. 93*e*, 93*f*, and 93*g*, can be overcome by adding stress-relief holes which (round before hardening) are from 0.001 to 0.0004 in. oval after the punch is hardened. The holes should be so located as not to interfere with screw and dowel holes. Figures 93*h* and 93*i* need no explanation.

In this connection it will be convenient to refer to Table 12 when comparing the hardness by Rockwell and Brinell testing-machine scales.

Table 12.—Comparative Hardness of Metals by Rockwell and Brinell Testing Machines.



Thickness of Stock Required for Accuracy
([illegible] impression in inches)

DPH	[illegible]	[illegible]	R_c	15 N	45 N	BHN
[illegible]	0.012	[illegible]	[illegible]	0.015	0.040	0.186
300	0.014	[illegible]	[illegible]	0.012	0.032	0.135
400	[illegible]	[illegible]	0.050	0.009	0.026	0.098
500	[illegible]	[illegible]	0.044	0.007	0.022	0.080
600	0.010	0.022	0.038	0.006	0.018	0.068
700	0.0092	0.020	0.033	0.005	0.016	—
800	0.0086	0.019	0.030	0.004	0.013	—
900	0.0081	0.018	0.027	0.003	0.012	—
1000	0.0076	0.017	0.025	0.003	0.010	—

Monotron tests at all hardnesses can be made on 0.018 in. stock. Scleroscope numbers vary with size; relations given are for 1 in. pieces.

CHAPTER XI

SPECIALIZATION

In starting a small shop it is well to consider the possibility, or at least the advisability, of specialization. To be successful, such a shop must have a field large enough to assure sufficient work of a particular kind to keep it fairly busy. It must also have men and equipment for handling special work efficiently so as to make it advisable for customers to go out of their way to be assured of satisfaction in this work.

In the beginning few small shops can afford to confine themselves to one class of work. In most cases specialized work grows until the regular run of work can be sent elsewhere. One advantage of such a course is that it permits one to try a number of classes of work before deciding on which to make the specialty. Then, too, it may never become advisable to confine work entirely to one class. If not, one or more men can be trained to be experts in some special line and the run-of-mine jobs handled by the rest of the shop.

One advantage of specialization is that it adds to the reputation of a shop and makes it legitimate to charge a higher rate for this kind of work. The specialty to be selected depends largely, if not entirely, on the nature of the community in which the

shop is located. In a farming district, the shop whose men can quickly and accurately determine the cause of failure or of unsatisfactory performance of any machine used in the community is a real asset to the town. It can add to the productivity of the district by getting the machines back to work in the shortest space of time and by saving the time and expense of going to some other town for repairs.

Such a community probably has many kinds of machine equipment, ranging from a small gasoline-driven generator set to large tractors and combines. In between are vacuum cleaners, washing machines, lawn mowers, sewing machines, egg beaters, and radios. Keeping these on the job will endear any small shop owner to the community, especially if repairs can be made promptly. This is especially necessary in haying time or when crops must be gathered in a hurry. Overtime work will be the rule instead of the exception, and it will be paid for gladly. A small shop in a certain mill town has kept the machinery running in the various mills there for over 50 years. The owner is one of the most respected men in town. His work on breakdown jobs has saved the mills and the community thousands of dollars, and he has been well paid for his work.

With the ever-growing use of automobiles many shops have built up a nice business by specializing on one or two makes of cars. For, although all cars have much in common, each has peculiarities that may puzzle a good man not familiar with that particular make or model.

One small shop, which specializes in repairs and

replacements for a widely known car, also offers a unique service to buyers of new cars of any make. He does not sell cars. But he is an expert on automobiles in general, and for a fixed fee, he tests any new car for a customer, under varying road conditions which his experience tells him will show up defects or maladjustments or any unsatisfactory performance. In most cases the defects are minor and can be adjusted by the agent after they are pointed out. But the owner never would find them until he was miles away from service stations.

Similar checks might be made on many other kinds of machines, such as tractors or combines, and would be worth far more to the customer than the amount of the fee.

Whether or not to attempt such specialization depends on a number of conditions, as has been pointed out. In any case it would probably be advisable to wait until a shop has been in operation long enough to feel out the market and to know for what kind of work the men are best fitted.

Charging for Special Work.—Handling general repair work, either of household appliances or farm machinery, is usually plain sailing as far as the work is concerned. But getting paid enough for it may be an entirely different matter. It frequently happens that some small appliances that cost but $2 or $3 when they were on the market will take several dollars' worth of time to repair. It is hard for the owner to understand why it should take so much time when they were sold at such a low price. He does not understand the difference between mass

production and handwork without the special tools that were used in making and assembling the device in the factory.

In order to avoid misunderstandings and hard feelings in such cases, the situation should be thoroughly understood before you begin work, and some idea as to the cost given. If new machines are available, it might be better to buy one, as it would probably cost less than the repairs on it. If they are not available, it is a question for the owner to decide how much he is willing to pay to have the use of his machine again. In normal times many concerns never attempt to repair some of their product but replace it with a new one at a very nominal cost, because they want to retain the customer and because there is no sales cost involved in this transaction. One large concern had a rule never to charge for any repair amounting to less than a dollar. They found that the cost of bookkeeping and of passing the charges through the different departments was more than the dollar. So they obtained a reputation for generosity by not charging, when in reality it was saving them money. This would not be the case in a small shop, but it should be remembered.

In repair work of this kind it often pays to make the charges as low as possible if it is likely to attract other work on which a fair profit can be made. That is one of the problems of business. No hard and fast rule can be made in matters of this kind. But it is seldom wise actually to lose money on a job, though it may sometimes pay to do so. If a new article is obtainable, it is better to urge its purchase

rather than to spend time repairing the old one when the cost runs too high.

On breakdown jobs in neighboring factories, where the loss of use of a damaged machine delays production, costs the owners a lot of money, and keeps people out of employment, every effort should be made to get the repair made as soon as possible even if it means working nights and Sundays, and interferes with your own personal plans for a fishing trip or other vacation. Service of this kind is usually appreciated by everyone concerned and will be paid for at a good rate, as it should be. One little shop, in a locality where there are a number of large textile and other mills, has made a good living for its owner for many years by handling work of this kind. He is an excellent mechanic whose ingenuity enables him to overcome many difficulties and get machines running in the shortest possible time. This has been appreciated by both the owners and the workers in his locality. And even though he is now nearly ninety years old, he does what he can to keep the mills going, often working alone on urgent jobs. He does not work at a low price, but his help is always worth fully as much as he charges, and everyone knows it.

Experimental Work.—The small shop very frequently has a customer with an idea that he wants made into something that will work. It is probably some gadget he has dreamed up, and he has little more than a very rough sketch to show you, sometimes not even that. You, being a good mechanic, are expected to take it and develop it into a world-

beating device in which there may be millions, according to the inventor. If you are interested in work of this kind, and nearly all mechanics are, you may want to play along with him and see what you can make of it.

There are two or three things to be considered, however. Will it interfere with the work you do for regular customers? Can the inventor pay for your work? What do you get out of the ideas you put into it? Too many men with the idea that there is a field for some new gadget get the notion that they have invented it because they thought of it first. This has been the attitude of some Army officers, especially in the field of aviation. Although you might never have tackled the job without a suggestion from the outside, the development of it may be entirely yours. If it does prove to be worth while, you deserve more than day wages for the work you have done.

Most important, perhaps, is making sure that the would-be inventor can pay what the job is worth. Unless you have good evidence that he can do so, it would be well to get a lump sum deposited to your credit in your bank, to be paid you as bills are rendered against the account. This is common practice with shops doing experimental work. You should also have an agreement in writing that a percentage of the profits from the sale of the device, either to someone else to manufacture or to customers, should come your way, as a reward for your development work. This would of course not be the case if the inventor had done all the inventing,

and you simply made the device in metal or other material.

Work of this kind should not be done at the regular hourly rate as it requires more than the manual labor expended on it. The know-how, which is the result of your previous experience and has cost you real money, should be paid for at considerably above the normal day rate. Not all inventors realize the amount of work that must be done to make their ideas at all workable.

Estimating on Work.—All shops, large and small, must do a lot of estimating on work before an order is given. This does not apply to all jobs but to enough so that you must be prepared to give a fairly close idea of the cost of a job before you take it. Materials vary widely in cost, but you must be in close enough touch with suppliers to know not only whether materials are available but also what they will cost delivered to your door. This may be the easiest part of preparing an estimate.

The following suggestions as to cutting time are from the "American Machinists' Handbook." For turning and boring:

Multiply the diameter in inches by 3.1416 and divide by 12 to give the circumference in feet. Divide the length of the cut in inches by the rate of feed per revolution. This gives the number of revolutions which the work must revolve. Multiplying the circumference by the number of revolutions gives the number of feet the tool must travel in making the cut. Dividing this by the cutting speed in feet per minute gives the cutting time in

minutes. Or

$$\frac{\text{Diameter} \times 3.1416 \times \text{length in inches}}{12 \times \text{speed} \times \text{feed in inches}} = \text{time in min.}$$

These data have been worked into a table of constants which save a lot of figuring. See Table 13. All you have to do is to multiply the length of the cut in inches and then by the constant for the cutting speed used. If a piece of work is 10 in. long and

TABLE 13.—CONSTANTS FOR CUTTING TIME IN MINUTES

Feed, in.	Cutting speed, ft. per minute—turning						
	20	25	30	35	45	55	65
Two cuts at:							
1/64 and 1/32	1.257	1.005	0.8378	0.7181	0.5581	0.4572	0.386
1/32 and 1/16	0.6283	0.5027	0.4189	0.3590	0.2793	0.2286	0.193
1/16 and 1/8	0.3142	0.2513	0.2094	0.1795	0.1396	0.1143	0.097
1/8 and 1/4	0.1571	0.1257	0.1047	0.0898	0.0698	0.0571	0.048
One cut at:							
1/64	0.8378	0.6702	0.5585	0.4787	0.3723	0.3046	0.257
1/32	0.4189	0.3351	0.2793	0.2394	0.1862	0.1523	0.128
1/16	0.2094	0.1676	0.1396	0.1197	0.0931	0.0761	0.064
1/8	0.1047	0.0838	0.0698	0.0598	0.0465	0.0381	0.032
1/4	0.0524	0.0419	0.0349	0.0299	0.0233	0.0191	0.016

4 in. in diameter with a cutting speed of 45 ft. per minute and there is only one cut 1/8 in. deep, we find the answer easily. The constant for this is 0.0465. So we have 10 × 4 × 0.0465, which gives 1.86 minutes for the cut. For other cutting speeds divide the constants by the multiplier used. For 200 ft. per minute divide the 20-column constant by 10.

Tables 14, 15, and 16 will also be found very helpful.

It Costs Money to Change Men.—Few who have not had actual experience realize the cost of firing and hiring men, even in a small shop. Although the average small shop must employ men with a fair amount of all-round experience, it pays to have a crew who are familiar with the type of work you are handling. It takes a new man some time to become thoroughly accustomed to any special class of work and to learn your methods of handling jobs. In shops with a lot of special machinery the cost of training new men or women usually varies from \$50 to \$200, and this is lost when an employee leaves for any cause whatever. For this reason, as well as for the advantage of having a crew of steady workers, changes in shop personnel are undesirable.

The record of a tool and die shop in the Middle West, employing less than 100 men, is interestingly outlined as follows:

> First of all, the plant is purposely kept small enough so that complete control is exercised by one man—the sole owner. This man has an abiding sense of responsibility toward his men. He expects a living for himself and for every employee, and positively refuses to be a party to chiseling tactics. Those who offer a large contract in return for cutting the rate in slack periods are invariably turned away. While the shop is operating, the men receive an average of \$1.40 per hour and are allowed to work as much as 68 hours per week, time and one-half being paid for hours in excess of 44. As a result, the men make over \$3,000 during a 7-month season. Second- and third-shift operation is definitely avoided. The shop does not work on Sunday.
>
> The plant is kept clean and modern in every respect.

TABLE 14.—CUTTING-SPEED CONVERSION TABLE

Surface Feet to Revolutions per Minute

Higher cutting speeds are easily found by multiplication. For 150 feet, use the 50 column and multiply by 3, or use the 75 column and multiply by 2. For 350 feet, use the 70 column and multiply by 5.

Feet per Minute

Diam., In.	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
	Revolutions per minute														
1/16	917	1,223	1,528	1,834	2,140	2,445	2,751	3,057	3,363	3,668	3,974	4,280	4,586	4,891	5,197
1/8	459	611	764	917	1,070	1,222	1,375	1,528	1,681	1,834	1,986	2,139	2,292	2,445	2,598
3/16	306	408	509	611	713	815	917	1,019	1,121	1,222	1,325	1,426	1,529	1,630	1,732
1/4	229	306	382	458	535	611	688	764	851	917	994	1,070	1,147	1,122	1,300
5/16	183	245	306	367	428	489	550	611	672	733	794	856	917	978	1,039
3/8	153	204	255	30[illegible]	357	408	458	509	560	611	662	713	764	815	865
7/16	131	175	218	262	306	349	393	437	481	524	568	611	656	699	743
1/2	115	153	191	229	268	306	344	382	420	459	497	535	573	611	649
9/16	102	136	170	204	238	272	306	340	373	407	441	475	509	543	577
5/8	91.8	123	153	184	214	245	276	306	337	367	398	428	459	489	520
11/16	83.3	111	138	167	194	222	249	273	300	333	360	389	416	444	472
3/4	76.3	102	127	153	178	203	229	254	279	306	330	357	381	408	432
13/16	71.1	94.8	119	142	166	190	213	237	261	284	308	332	356	379	403
7/8	65.5	87.3	109	131	153	175	196	219	241	262	285	306	329	349	372
15/16	61.0	81.4	101	122	142	163	183	204	224	244	265	285	305	326	346
1	57.3	76.4	95.5	115	134	153	172	191	210	229	258	267	287	306	325
1 1/16	53.9	71.8	89.9	108	126	144	162	180	197	215	233	251	269	287	305
1 1/8	51.0	68.0	85.0	102	119	136	153	170	187	204	221	238	255	272	289

1 3/16	48.3	64.4	80.5	96.6	113	129	145	161	177	193	209	225	242	258	274
1 1/4	45.8	61.2	76.3	91.8	107	123	137	153	168	183	199	214	230	245	260
1 5/16	43.6	58.2	72.8	87.3	102	116	131	146	160	175	189	204	218	233	247
1 3/8	41.7	55.6	69.5	83.3	97.2	111	125	139	153	167	180	195	208	222	236
1 7/16	39.8	53.0	66.3	79.5	92.8	106	119	133	146	159	172	186	199	212	225
1 1/2	38.2	50.8	63.7	76.3	89.2	102	115	127	140	153	165	178	191	204	216
1 9/16	36.6	48.8	61.0	73.2	85.4	97.6	110	122	134	146	159	171	183	195	207
1 5/8	35.0	47.0	58.8	70.5	82.2	93.9	106	117	129	141	152	165	176	188	199
1 11/16	33.9	45.2	56.5	67.8	79.1	90.4	102	113	124	136	147	158	170	181	192
1 3/4	32.7	43.6	54.5	65.5	76.4	87.3	98.2	109	120	131	142	153	164	175	185
1 13/16	31.7	42.2	52.8	63.3	73.9	84.4	95.0	106	119	127	137	148	158	169	179
1 7/8	30.6	40.7	50.9	61.1	71.3	81.5	91.9	102	112	122	133	143	153	163	173
1 15/16	29.6	39.4	49.3	59.1	69.0	78.8	88.7	98.5	108	118	128	138	148	158	167
2	28.7	38.2	47.8	57.3	66.9	76.4	86.0	95.5	105	115	124	134	143	153	162
2 1/8	27.0	36.0	45.0	54.0	63.0	72.0	81.0	90.0	99.0	108	117	126	135	144	153
2 1/4	25.4	34.0	42.4	51.0	59.4	68.0	76.2	85.5	93.5	102	111	119	128	136	145
2 3/8	24.2	32.2	40.3	48.3	56.4	64.4	72.5	80.5	88.6	96.6	105	113	121	129	137
2 1/2	22.9	30.6	38.2	45.8	53.5	61.2	68.8	76.3	84.2	91.7	99.5	107	114	122	130
2 5/8	21.8	29.0	36.3	43.5	50.8	58.0	65.3	72.5	79.8	87.0	94.3	102	109	116	123
2 3/4	20.8	27.8	34.7	41.7	48.6	55.6	62.5	69.5	76.5	83.4	90.4	97.2	104	111	118
2 7/8	19.8	26.4	33.0	39.6	46.2	52.8	59.4	66.0	72.6	79.2	85.8	92.4	99.0	106	112
3	19.1	25.5	31.8	38.2	44.6	51.0	57.3	63.7	69.9	76.4	82.6	89.1	95.3	102	108
3 1/8	18.3	24.4	30.5	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	104
3 1/4	17.6	23.4	29.3	35.1	41.0	46.8	52.7	58.5	64.4	70.2	76.1	81.9	87.8	93.6	99.5
3 3/8	17.0	22.6	28.3	33.9	39.6	45.2	50.9	56.5	62.2	67.8	73.5	79.1	84.8	90.4	96.1
3 1/2	16.4	21.8	27.3	32.7	38.2	43.6	49.1	54.5	60.0	65.5	70.8	76.4	81.8	87.4	92.7
3 5/8	15.8	21.0	26.3	31.5	36.8	42.0	47.3	52.5	57.8	63.0	68.3	73.5	78.8	84.0	89.3
3 3/4	15.3	20.4	25.5	30.6	35.7	40.8	45.9	51.0	56.1	61.2	66.3	71.4	76.5	81.6	86.7

TABLE 14.—CUTTING-SPEED CONVERSION TABLE—*Continued*

Surface Feet to Revolutions per Minute

Higher cutting speeds are easily found by multiplication. For 150 feet, use the 50 column and multiply by 3, or use the 75 column and multiply by 2. For 350 feet, use the 70 column and multiply by 5.

Diam., In.	Feet per Minute														
	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
	Revolutions per minute														
3⅞	14.8	19.7	24.6	29.6	34.5	39.4	44.3	49.3	54.2	59.1	64.0	69.0	73.8	78.8	83.7
4	14.3	19.1	23.9	28.7	33.4	38.2	43.0	47.8	52.6	57.3	62.1	66.9	71.7	76.4	81.3
4¼	13.5	18.0	22.5	26.9	31.4	35.9	40.4	44.9	49.4	53.9	58.4	62.9	67.4	71.8	76.3
4½	12.7	16.9	21.2	25.4	29.6	34.0	38.2	42.4	46.6	51.0	55.1	59.4	63.6	67.9	72.1
4¾	12.1	16.1	20.1	24.1	28.1	32.2	36.2	40.2	44.2	48.2	52.3	56.3	60.3	64.3	68.3
5	11.5	15.3	19.1	22.9	26.7	30.6	34.4	38.2	42.0	45.9	49.7	53.5	57.3	61.1	64.9
5¼	10.9	14.5	18.2	21.8	25.4	29.1	32.7	36.4	40.0	43.6	47.3	50.9	54.5	58.2	61.8
5½	10.4	13.9	17.4	20.8	24.3	27.8	31.3	34.7	38.2	41.7	45.1	48.6	52.0	55.6	59.0
5¾	10.0	13.3	16.6	19.9	23.2	26.6	29.9	33.2	36.5	39.8	43.2	46.5	49.8	53.1	56.4
6	9.6	12.7	15.9	19.1	22.3	25.5	28.7	31.8	35.0	38.2	41.3	44.6	47.7	51.0	54.0
6¼	9.2	12.2	15.3	18.3	21.4	24.4	27.5	30.6	33.6	36.7	39.7	42.8	45.8	48.9	51.9
6½	8.8	11.7	14.7	17.6	20.5	23.5	26.4	29.4	32.3	35.2	38.2	41.1	44.0	47.0	49.9
6¾	8.5	11.3	14.2	17.0	19.8	22.6	25.5	28.3	31.1	34.0	36.8	39.6	42.5	45.3	48.1
7	8.1	10.9	13.6	16.4	19.1	21.8	24.6	27.3	30.0	32.7	35.5	38.2	41.0	43.7	46.0
7¼	7.9	10.5	13.2	15.8	18.4	21.1	23.7	26.4	29.0	31.6	34.3	36.9	39.5	42.2	44.8
7½	7.6	10.2	12.7	15.3	17.8	20.4	22.9	25.4	28.0	30.5	33.2	35.6	38.2	40.7	43.3
7¾	7.4	9.8	12.3	14.8	17.2	19.7	22.1	24.6	27.1	29.5	32.0	34.4	36.9	39.4	42.8
8	7.2	9.6	11.9	14.3	16.7	19.1	21.1	23.9	26.3	28.7	31.0	33.4	35.9	38.2	40.6

TABLE 15.—TIME REQUIRED FOR TOOL TO TRAVEL 1 INCH When Feed Is 1/100 In. per Revolution

Diameter, in.	Surface speed per minute															
	20		25		30		35		40		45		50		60	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1/4	0	20	0	16	0	13	0	11	0	10	0	9	0	8	0	7
5/16	0	25	0	20	0	17	0	14	0	13	0	11	0	10	0	9
3/8	0	29	0	23	0	19	0	17	0	15	0	13	0	12	0	10
7/16	0	34	0	27	0	23	0	19	0	17	0	15	0	14	0	12
1/2	0	39	0	31	0	26	0	22	0	20	0	17	0	17	0	13
9/16	0	44	0	35	0	29	0	25	0	22	0	19	0	18	0	15
5/8	0	49	0	39	0	32	0	28	0	25	0	22	0	20	0	16
11/16	0	54	0	43	0	36	0	31	0	27	0	24	0	22	0	18
3/4	0	59	0	47	0	39	0	34	0	30	0	26	0	24	0	20
13/16	1	4	0	51	0	42	0	36	0	32	0	28	0	26	0	21
7/8	1	9	0	55	0	46	0	39	0	35	0	30	0	28	0	23
15/16	1	14	0	59	0	49	0	42	0	37	0	33	0	30	0	25
1	1	19	1	3	0	52	0	45	0	40	0	35	0	32	0	26
1 1/8	1	28	1	10	0	58	0	50	0	44	0	39	0	35	0	29
1 1/4	1	38	1	18	1	5	0	56	0	49	0	43	0	39	0	33
1 3/8	1	48	1	26	1	11	1	2	0	54	0	48	0	43	0	36
1 1/2	1	58	1	34	1	18	1	7	0	59	0	52	0	47	0	39
1 5/8	2	8	1	42	1	24	1	13	1	4	0	56	0	51	0	42
1 3/4	2	18	1	50	1	31	1	19	1	9	1	1	0	55	0	46
1 7/8	2	27	1	58	1	37	1	24	1	14	1	5	0	59	0	49
2	2	37	2	6	1	44	1	29	1	19	1	9	1	3	0	52
2 1/8	2	46	2	13	1	50	1	34	1	23	1	13	1	6	0	55
2 1/4	2	56	2	21	1	56	1	40	1	28	1	17	1	11	0	58
2 3/8	3	6	2	29	2	3	1	46	1	33	1	22	1	15	1	2
2 1/2	3	16	2	37	2	9	1	52	1	38	1	26	1	19	1	5
2 3/4	3	37	2	54	2	23	2	4	1	49	1	35	1	27	1	12
3	3	56	3	9	2	36	2	15	1	58	1	44	1	34	1	18
3 1/4	4	16	3	25	2	49	2	26	2	8	1	53	1	42	1	25
3 1/2	4	35	3	40	3	2	2	37	2	18	2	1	1	50	1	31
3 3/4	4	56	3	57	3	15	2	49	2	28	2	10	1	58	1	38
4	5	14	4	11	3	27	2	59	2	37	2	18	2	6	1	44
4 1/4	5	33	4	26	3	40	3	10	2	47	2	27	2	13	1	50

TABLE 15.—TIME REQUIRED FOR TOOL TO TRAVEL 1 INCH When Feed Is 1/100 In. per Revolution—(*Continued*)

Diameter, in.	Surface speed per minute															
	20		25		30		35		40		45		50		60	
4½	5	52	4	42	3	52	3	21	2	56	2	35	2	21	1	56
4¾	6	12	4	58	4	6	3	32	3	6	2	44	2	29	2	3
5	6	32	5	14	4	19	3	43	3	16	2	52	2	37	2	10
5½	7	15	5	48	4	47	4	8	3	37	3	11	2	54	2	24
6	7	52	6	18	5	12	4	29	3	56	3	28	3	9	2	36
6½	8	33	6	50	5	39	4	52	4	17	3	46	3	25	2	50
7	9	10	7	20	6	3	5	14	4	35	4	2	3	40	3	2
7½	9	54	7	55	6	32	5	39	4	57	4	21	3	58	3	16
8	10	28	8	22	6	54	5	58	5	14	4	36	4	11	3	27
8½	11	7	8	54	7	20	6	20	5	34	4	53	4	27	3	40
9	11	46	9	25	7	46	6	42	5	53	5	11	4	42	3	53
9½	12	25	9	56	8	12	7	5	6	12	5	28	4	58	4	6
10	13	9	10	31	8	40	7	30	6	34	5	47	5	16	4	20
10½	13	40	10	56	9	2	7	47	6	50	6	1	5	28	4	31
11	14	30	11	36	9	34	8	16	7	15	6	23	5	48	4	47
11½	15	2	12	2	9	55	8	34	7	31	6	37	6	1	4	58
12	15	44	12	35	10	23	8	58	7	52	6	55	6	18	5	14
12½	16	24	13	7	10	49	9	21	8	12	7	13	6	34	5	25
13	17	4	13	39	11	16	9	44	8	32	7	31	6	50	5	38
13½	17	32	14	2	11	34	10	0	8	46	7	43	7	1	5	47
14	18	20	14	40	12	6	10	27	9	10	8	4	7	20	6	3
14½	18	52	15	6	12	28	10	46	9	26	8	19	7	33	6	14
15	19	38	15	41	12	57	11	10	9	49	8	38	7	50	6	29
15½	20	24	16	19	13	28	11	38	10	12	9	0	8	10	6	44
16	20	58	16	46	13	50	11	57	10	29	9	13	8	23	6	55

TABLE 16.—LATHE AND BORING-MILL TIME

Diam. of work	Cutting speed, ft. per minute							
	25				30			
	Feeds, in. per rev.				Feeds, in. per rev.			
	1/32	1/8	1/4	1/2	1/32	1/8	1/4	1/2
2	8.042	2.011	1.005	0.503	6.702	1.675	0.838	0.419
2½	10.053	2.513	1.257	0.628	8.378	2.094	1.047	0.524
3	12.064	3.016	1.508	0.754	10.053	2.513	1.257	0.628
3½	14.074	3.519	1.759	0.880	11.729	2.932	1.466	0.733
4	16.085	4.021	2.011	1.005	13.404	3.351	1.676	0.838
4½	18.096	4.524	2.262	1.131	15.080	3.770	1.885	0.942
5	20.106	5.027	2.513	1.257	16.755	4.189	2.094	1.047
5½	22.117	5.529	2.765	1.382	18.431	4.608	2.304	1.152
6	24.127	6.032	3.016	1.508	20.106	5.027	2.513	1.257
6½	26.138	6.535	3.267	1.634	21.782	5.445	2.723	1.361
7	28.149	7.037	3.519	1.759	23.457	5.864	2.932	1.466
7½	30.159	7.540	3.770	1.885	25.133	6.283	3.142	1.571
8	32.170	8.042	4.021	2.011	26.808	6.702	3.351	1.676
8½	34.181	8.545	4.273	2.136	28.484	7.121	3.560	1.780
9	36.191	9.048	4.524	2.262	30.159	7.540	3.770	1.885
9½	38.202	9.550	4.775	2.388	31.835	7.959	3.979	1.990
10	40.212	10.053	5.027	2.513	33.510	8.378	4.189	2.094
10½	42.223	10.556	5.278	2.639	35.186	8.796	4.398	2.199
11	44.234	11.058	5.529	2.765	36.861	9.215	4.608	2.304
11½	46.244	11.561	5.781	2.890	38.537	9.634	4.817	2.499
12	48.255	12.064	6.032	3.016	40.212	10.053	5.027	2.513
12½	50.266	12.566	6.283	3.142	41.888	10.472	5.236	2.618
13	52.276	13.069	6.535	3.267	43.564	10.891	5.445	2.723
13½	54.287	13.572	6.786	3.393	45.239	11.310	5.655	2.827
14	56.297	14.074	7.037	3.519	46.915	11.729	5.864	2.932
14½	58.308	14.577	7.289	3.644	48.590	12.148	6.074	3.037
15	60.319	15.080	7.540	3.770	50.266	12.566	6.283	3.142
15½	62.329	15.582	7.791	3.896	51.941	12.985	6.493	3.246
16	64.340	16.085	8.042	4.021	53.617	13.404	6.702	3.351
16½	66.351	16.588	8.294	4.147	55.292	13.823	6.912	3.456
17	68.361	17.090	8.545	4.273	56.968	14.242	7.121	3.560
17½	70.372	17.593	8.796	4.398	58.643	14.661	7.330	3.665
18	72.382	18.096	9.048	4.524	60.319	15.080	7.540	3.770
18½	74.393	18.598	9.299	4.650	61.994	15.499	7.749	3.875
19	76.404	19.101	9.550	4.775	63.670	15.917	7.959	3.979
19½	78.414	19.604	9.802	4.901	65.345	16.336	8.168	4.084
20	80.425	20.106	10.053	5.027	67.021	16.755	8.378	4.189
21	84.446	21.112	10.556	5.278	70.372	17.593	8.796	4.398
22	88.467	22.117	11.058	5.529	73.723	18.431	9.215	4.608
23	92.489	23.122	11.561	5.781	77.074	19.268	9.634	4.817
24	96.510	24.127	12.064	6.032	80.425	20.106	10.053	5.027
25	100.53	25.133	12.566	6.283	83.776	20.944	10.472	5.236
26	104.55	26.138	13.069	6.535	87.127	21.782	10.891	5.445
27	108.57	27.143	13.572	6.786	90.478	22.620	11.310	5.655
28	112.59	28.149	14.074	7.037	93.829	23.457	11.729	5.864
29	116.62	29.154	14.577	7.289	97.180	24.295	12.148	6.074
30	120.64	30.159	15.080	7.540	100.53	25.133	12.566	6.283

TABLE 16.—LATHE AND BORING-MILL TIME—(*Continued*)

Diam. of work	Cutting speed, ft. per minute							
	35				40			
	Feeds, in. per Rev.				Feeds, in. per rev.			
	1/32	1/8	1/4	1/2	1/32	1/8	1/4	1/2
2	5.745	1.436	0.718	0.359	5.027	1.257	0.628	0.314
2½	7.181	1.795	0.898	0.449	6.283	1.571	0.785	0.393
3	8.617	2.154	1.077	0.539	7.540	1.885	0.942	0.471
3½	10.053	2.513	1.257	0.624	8.796	2.199	1.100	0.550
4	11.489	2.872	1.436	0.718	10.053	2.513	1.257	0.628
4½	12.925	3.231	1.616	0.808	11.310	2.827	1.414	0.707
5	14.362	3.590	1.795	0.898	12.566	3.142	1.571	0.785
5½	15.798	3.949	1.975	0.987	13.823	3.456	1.728	0.864
6	17.234	4.308	2.154	1.077	15.080	3.770	1.885	0.942
6½	18.670	4.668	2.334	1.167	16.336	4.084	2.042	1.021
7	20.106	5.027	2.513	1.257	17.593	4.398	2.199	1.100
7½	21.542	5.386	2.693	1.346	18.850	4.712	2.356	1.178
8	22.979	5.745	2.872	1.436	20.106	5.027	2.513	1.257
8½	24.415	6.104	3.052	1.526	21.363	5.341	2.670	1.335
9	25.851	6.463	3.231	1.616	22.620	5.655	2.827	1.414
9½	27.287	6.822	3.411	1.705	23.876	5.969	2.985	1.492
10	28.723	7.181	3.590	1.795	25.133	6.283	3.142	1.571
10½	30.159	7.540	3.770	1.885	26.389	6.597	3.299	1.649
11	31.596	7.899	3.949	1.975	27.646	6.912	3.456	1.728
11½	33.032	8.258	4.129	2.064	28.903	7.226	3.613	1.806
12	34.468	8.617	4.308	2.154	30.159	7.540	3.770	1.885
12½	35.904	8.976	4.488	2.244	31.416	7.854	3.927	1.964
13	37.340	9.335	4.668	2.334	32.673	8.168	4.084	2.042
13½	38.776	9.694	4.847	2.424	33.929	8.482	4.241	2.121
14	40.212	10.053	5.027	2.513	35.186	8.796	4.398	2.199
14½	41.649	10.412	5.206	2.603	36.443	9.111	4.555	2.278
15	43.085	10.771	5.386	2.693	37.699	9.425	4.712	2.356
15½	44.521	11.130	5.565	2.783	38.956	9.739	4.869	2.435
16	45.957	11.489	5.745	2.872	40.212	10.053	5.027	2.513
16½	47.393	11.848	5.924	2.962	41.469	10.367	5.184	2.592
17	48.829	12.207	6.104	3.052	42.726	10.681	5.341	2.670
17½	50.266	12.566	6.283	3.142	43.982	10.996	5.408	2.749
18	51.702	12.925	6.463	3.231	45.239	11.310	5.655	2.828
18½	53.138	13.284	6.642	3.321	46.496	11.624	5.812	2.906
19	54.574	13.644	6.822	3.411	47.752	11.938	5.969	2.985
19½	56.010	14.003	7.001	3.501	49.009	12.252	6.126	3.063
20	57.446	14.362	7.181	3.590	50.266	12.566	6.283	3.142
21	60.319	15.080	7.540	3.770	52.779	13.195	6.597	3.299
22	63.191	15.798	7.899	3.949	55.292	13.823	6.912	3.456
23	66.063	16.516	8.258	4.129	57.805	14.451	7.226	3.613
24	68.936	17.234	8.617	4.308	60.319	15.080	7.540	3.770
25	71.808	17.952	8.976	4.488	62.832	15.708	7.854	3.927
26	74.680	18.670	9.335	4.668	65.345	16.336	8.168	4.084
27	77.553	19.388	9.694	4.847	67.859	16.965	8.482	4.241
28	80.425	20.106	10.053	5.027	70.372	17.593	8.796	4.398
29	83.297	20.824	10.412	5.206	72.885	18.221	9.111	4.555
30	86.170	21.542	10.771	5.386	75.398	18.850	9.425	4.712

For speeds of 50, 60, 70, and 80 ft. per minute, divide these time values by 2. For speeds of 75, 90, 105, and 120 ft. per minute, divide by 3. Other speed values can be found in the same way.

Self-respecting workmen keep themselves clean, likewise their machines and adjacent working space. The proprietor sees that washrooms are maintained spotless and provides awnings to keep out the glare of the sun through large window areas. Water coolers have extra space for men to keep lunches and milk on ice. Soft-drink dispensing machines are available. Fans on the overhead gas-fired unit heaters are kept running on warm days to stir up the air. A fenced parking lot protects employees' automobiles. Equipment is maintained in first-class condition and is replaced whenever a new machine will pay for itself in two years. Operators appreciate the timesaving features of conveniently grouped controls and wide speed and feed ranges on up-to-date machines. Furthermore, machines are ordered with such attachments and accessories that will permit the widest number of operations in one setup, avoiding waiting for another machine. For example, all shapers have universal tables so that angle cuts can be made without going to another unit.

Accurate pricing of work is another reason for employee satisfaction. Both the proprietor and his superintendent are able to figure costs accurately, in contrast to many jobbing shops. Thus, there is no need to chisel on wages or quality in order to come out even or make a profit. Customer acceptance has been built up for good work at the right price. In consequence, the men work a full season year after year. Furthermore, they get the highest grade of die and tool work, which is important to highgrade mechanics.

Craft unionism was definitely encouraged by the manager, who saw to it, however, that the best interests of the men were protected when writing the contract. For example, seniority was flatly rejected on the ground that the best men should be laid off last. Surprisingly enough, the business agent agreed to the principle that, among

skilled men, those who make the best use of their talents should have the opportunity for longest employment. On the other hand the business agent had proposed that wage rates fluctuate with the condition of business. To this the manager replied that such a clause opens the way to wage chiseling.

In this shop, there is a certain amount of practical paternalism. This may range from providing free beer for the company picnic to paying all medical and hospital expenses for men and their families requiring surgical treatment of any kind. Despite high annual wages, skilled workmen find such expenses to be onerous. The business pays enough, because of the way it is run to take care of these outlays. It is impossible to hire men away from this shop.

THE FOREMAN'S JOB

Foreman training is a subject that comes up with fair regularity. Every manager admits the value of good foremen, but there are no standard specifications as to what constitutes the desired qualities. The main reason is that managers themselves are not agreed as to the duties or qualifications. Although the qualifications must of necessity vary with the size of the plant, the greatest variation is due to differences in the management and the plant organization.

Thirty years ago the strong-arm, driving type of foreman was all too common. He reflected the ideas of the management, which have, fortunately, changed in nearly all industries. Gone too, in most cases, is the demand for a foreman who will act as

informer on the private lives of his men and be a buffer in all arguments as to wages and hours.

There still exist, however, varied ideas on the part of management. These range from the working foreman to that of a small shop proprietor, solely responsible for the efficient operation of his department. In between, we have those who expect a foreman to be an instructor, tool designer, inspector, stock chaser, clerk, and employment man. In the small shop he must often perform several of these functions.

Before we can have really satisfactory training, it seems necessary to determine how many of these functions he should perform. It is the duty of management to decide what the foreman's job really is.

BITS REGARDING PERSONNEL

Don't let your foremen get the idea that you expect them to furnish all the bright ideas from their departments. This tempts them to claim suggestions made by their men. Urge them to encourage their men by giving them full credit.

Suggestion boxes produce excellent results when they are properly conducted. But they do not run themselves. Every suggestion should have careful consideration. If it is not practical, the reason should be clearly explained. If good, it must be suitably rewarded. Proper rewards require excellent judgment as to adoption and value. Unless you have someone who can conduct a suggestion box properly, don't start it!

Pick your personnel manager as carefully as you

do your production superintendent. He may be just as valuable. Don't get the idea that it's a job for a man, or woman, who has failed at everything else. It's a real job and can be made to pay real dividends.

Have your application blanks short and don't ask questions that are none of your business anyhow. You'd be peeved as a pup at a lot of questions a man looking for a job is supposed to answer. You may need his production just as much as he needs a job, so don't antagonize him.

In the days of the small shop the boss knew his men's first names and when Johnny or Susie had the measles. A turkey plus a handshake at Christmas meant a lot to the men. In big shops the personnel man has to represent the boss. See that he does it well. And the more often the big boss can get out into the shop, the better.

Don't expect that your foremen will never make mistakes. If they were that good they'd probably have your job.

CHAPTER XII

OVERHEAD

When a man graduates from the bench or machine into a shop of his own, he usually takes on more problems and responsibilities than he realizes. For no matter how good a mechanic he is or how much he has earned, it is very hard for him to realize all the factors that go to make up the cost of running a business.

If he had been getting 75 cents an hour and his boss charged $1.50 an hour for his time, he probably thought he was being exploited, that the customer was being cheated, and that the boss was making oodles of money. In reality none of these things was probably true, and unless the boss knows more about business than the average, he may be among the failures in the near future.

One of the greatest obstacles to be met in running a small shop successfully is the competition of other small shops whose bosses do not know their costs or what they should charge for their service. This same trouble affects many fairly large shops as well. And although the shops that undercharge do not last very long, they make it very hard for those that survive. It is quite natural for a mechanic to feel that if he can get twice as much per hour as he did at the bench, he must be making money, but this is not always the case.

The first thing to learn is that wages paid out are not the only items that go to make up the cost of doing work. In some large industries direct wages are but a small part of the ultimate cost. The other items that go to make up the total expense of doing business must be understood if one is to operate successfully.

Whether you own your own building or not, you must charge yourself "rent" for it. For if the money you paid for the shop had been invested in good bonds, it would pay about 3 per cent interest. So you had better charge yourself 3 per cent on the investment, plus the cost of taxes, insurance, repairs, and some depreciation, depending on the type of building. These are overhead, or fixed, charges and can be summed up about as follows for a shop costing $20,000:

Overhead or fixed charges based on a 9-hr. day for 300 days per year, or 2,700 hr. per year:

Interest at 6 per cent, or rent	$1,200
Taxes at $30 per $1,000	600
Insurance	60
Depreciation and repairs, 10 per cent	2,000
Total	$3,860
Plant overhead per hour	$1.43
Light, heat, janitor work, office work	Not charged here
Hourly overhead:	
For a 50-hr. week	$1.544
For a 44-hr. week	$1.755

In order to know how this affects the cost of work,

the carrying or overhead charges of $3,860 per year have been translated into the charge per hour. To get the rate per man, it is simply necessary to divide the hourly charge by the number of men at work.

In addition to the plant charges there are charges for the use of machines and tools, the cost of supervision, office work, janitors, handy men, and trucks if any are used. The figures given are for the bare plant with benches, vises, etc., but not for its machine equipment.

If a job comes in that requires only a bench vise and a file, it should not be charged at the same rate per hour as though it required expensive machines or costly tools. In such a case only the plant overhead would be charged, plus direct labor, supervision, office expense, and profit.

If, however, the job requires the use of a machine costing $1,000, it is clear that a greater charge per hour is justified. For the interest on the money invested in the machine must be considered, also the cost of depreciation and repairs on it. At 6 per cent interest on the cost of the machine this would be 2.37 cents per hour for a 50-hr. week.

Allowance for depreciation varies with the kind of machine. For a standard tool such as a lathe, 10 per cent is usual. For machines that wear out rapidly or become obsolete, a higher rate is allowed. The job shop will generally be equipped with machines of standard make for which 10 per cent is ample. But this should be charged in order to replace the machines when necessary. At 10 per cent the depreciation charge is 4 cents per hour on

the 50-hr. week basis. Then you must add the cost of power at about 2 cents per horsepower-hour or, say, 10 cents per hour for a 5-hp. motor on a machine. These costs add up to a total charge of about 16 cents per hour.

Just how much of this plant cost should be added to the job on the machine depends on conditions. By dividing this by the average number of men in the shop, the charge might be 15.44 cents per hour for a 50-hr. week. But even this isn't all. The boss must be paid for his work in getting the job and for supervision. He must also make a profit to permit the purchase of new equipment and to provide a surplus for the jobs that do not pay, likewise for times when work is scarce. Then there is the material used and the mechanic's time, both of these being easy to figure. The cost of the money lying idle in material sometimes becomes quite a factor also

Overhead fixed charges on machine costing $1,000, based on a 50-hr. week, or an interest charge of 2.37 cents per hour:

	Charges for depreciation and repair at		
	10%	15%	20%
Charges per hour	3.7¢	5.6¢	7.4¢
2¢ per hp. for 5 hp. added	13.7¢	15.6¢	17 4¢
Interest charge, 2.37¢, added	16.07¢	17.97¢	19.77¢

Figuring up the costs so far, we have, for a 10-man

shop, an hourly overhead of:

Plant overhead, interest, taxes, etc. . .	$0.1544
Machine overhead: interest, depreciation, power	0.1600
Overhead total	$0.3144
Man's wage	0.7500
Total	$1.0644

Allowing the boss $1.50 per hour for his time and dividing this among the 10 men gives 15 cents per hour, or a total of $1.2144. Add another $1.50 per hour as shop profit, which is very low when we consider the $20,000 investment in plant and probably as much more in machine equipment. This makes another 15 cents per man and gives $1.3644 per hour without allowing for postage, carting, bookkeeper, or office boy.

All this detail has been given to show that the common charge of $1.50 per hour for a man's time is really very low and that even if he gets but half of this, the boss has to watch details very closely to come out whole at the end of the year. Actual figures have been given to show how costs can be determined to suit each shop, no matter what its size. It must be remembered that few mechanics now get as little as 75 cents per hour.

As has been shown, the shop or plant cost is almost independent of the number of men employed. If only one man is at work, the whole shop cost of $1.544 should be charged against his time. But we know that this cannot be done as it would be unfair to the customer who is not to blame because your

shop is not busy. Then, too, such a charge would soon drive away all your customers. So we generally adopt an average charge regardless of the number of men at work.

In a similar way, some shops charge the same hourly rate whether a man works at a bench or on an expensive machine. This method however has less justification than the other, and it is better to have a fixed charge for the use of each of the more expensive machines in a shop. As maintenance of high-cost machines is quite an item in shop expense, it will usually be found a real economy to pay a little more than the average wage to men who run them. In most cases this extra wage is more than saved in repairs and in preventing loss of use of the machine.

Things to Consider.—The author has considered the problems of starting a small shop for many years. Two different articles along this line, written under one of his pen names, John R. Godfrey, and published in the *American Machinist* about 25 years ago, are here reproduced; also an article on the cost of supervision and overhead, in more serious vein, published in 1919. Many of the problems remain the same and should be carefully considered before capital is risked in a new venture.

PROBLEMS OF STARTING A NEW BUSINESS

A friend of mine has just accepted a position (we would have said he "got a job" a few years ago) as chief cook and bottle washer in a little shop manufacturing a new brand of cockscrews. The inventor is an ex-waiter who had evidently lived on the left-

overs and saved all his tips. He devised a corkscrew whereby the happy owner of a bottle with a reluctant cork can extract the barrier standing between him and the liquid joy within by a slight twist of the wrist and jerk of the right elbow.

Fortunately for the inventor, my friend Johnson is an excellent mechanic and has been brought up in a small shop. The advantages of this will be seen later when we see some of the temptations and conspiracies that confront the proprietor of the small shop just starting in to manufacture a new device.

As with practically every other object on earth, there are several ways in which it might be manufactured. If there was a demand for a million a minute, special machines could easily be devised for making them in enormous quantities and at an astonishingly low price. It is even possible that they might be made on special millers of the thread-cutting variety a little more economically than on the punch press, which was decided upon by Johnson as the best machine to use at the start.

When the machinery salesmen got the tip that Mr. Ex-waiter intended to equip a small factory to make double-action corkscrews, they naturally swarmed in on him as though he was the only important prospect in the East. And the kinds of machines some of them tried to sell him constituted a crime. Automatic screw machines, both single and multiple spindle; hand screw machines; millers of various kinds, and punch presses galore, were all proposed as being the only thing available for economical production. Worst of all, there is a half

truth behind every case, which makes it all the harder for the unsuspecting victim, who only knows what he wants to make and has mighty few ideas as to how the making should be done.

One salesman for a special miller looked the situation over and advised the purchase of the punch press instead of one of his machines. According to Johnson, his talk was something like this:

My miller will give you the very best results at extremely low-cost production, but it will only make a part of your corkscrew. If you had an established business and required the maximum output, it would pay you to buy one of these machines, even though the cost is $2,000. But you have an undeveloped market; you do not know how many of these will be needed and, until you do, it is very foolish to invest unnecessarily and go into special refinements in manufacture. A good punch press, which you can probably buy for $600, will make all the parts of your corkscrew. And even though it does not make the double back-action handle as well or as quickly as my machine would do it, it will be plenty good enough for the beginning, and will let you feel you way until you know how large a production you need.

I have seen so many shops, starting on a new product, go to the wall because they spent all of their capital on equipment instead of reserving enough for exploitation of the article made, that I do not intend to be a party to any such proceeding. When the time comes that you require a large output, I want the opportunity of bidding for an outfit to manufacture those handles on one of my machines, but at the present time I would not willingly sell you one of these machines, because I do not believe it is what you want.

After the salesman went out and Johnson and his boss had recovered their breath, they talked the matter over carefully and decided that he was right, and the boss made a memorandum of that salesman's name for future reference.

The reason I believe Johnson is just the man for him is almost explained by the argument of the salesman for buying the punch press instead of the special miller. A man who is accustomed to a large manufacturing plant, where quantities are sufficient to warrant the installation of special machinery and where it is economy to supply every convenience and appliance for the workmen, cannot appreciate the problems of the small shop, especially one just starting in business.

Special kinks and devices must be fudged up to meet conditions as they arise, it being absolutely impossible to have all the tools and fixtures that are essential in the large shop. But while a man is feeling his way, he must aim to get out his product with as small an investment for equipment as possible, even if the individual pieces do cost a little more than they would if made on a special machine.

One glaring case of this kind which comes to mind is that of a friend who was an expert engine-lathe builder, who severed his connection with his old concern and started in on his own hook. He was an excellent mechanic, knew how to build lathes as they should be, and was a splendid designer of fixtures for economical production. This was his undoing.

He designed and built fixtures for every part of

his lathe before starting to manufacture and, although this might have worked out if he had secured contracts taking care of his entire output, it completely tied up his available capital so that he had nothing in reserve for the exploitation of his new product. So he very naturally lasted but a short time, to the delight of his competitors and to his everlasting disappointment.

All of this goes to show that there are many things to consider in manufacturing articles of any kind. There are no hard and fast rules that can be laid down for machine-shop equipment. There is no one machine best for any operation under all conditions. Fortunately there are some salesmen who believe that it pays to consider the customer's problems as though they were his own. An excellent man in a large shop may be the very poorest adviser in a shop with limited capital.

UNCLE BILL EXPLAINS ABOUT "OVERHEAD"

"You know, Godfrey," said Johnson, as we were philosophizing the other day, "I'm not much on this secret stuff in the shop. I wouldn't hire spotters in my shop if I had to quit tomorrow. Why, even old Jack Harper, who hires 'em once in a while, said they were the most unreliable birds he ever met. Always trying to find out what kind of a report you want—and then dig up evidence to suit.

"So, knowing how I feel, you may wonder how I got this," and he pointed to some typewritten sheets. "It's a verbatim report of a confab between little

Jimmie Smith and Uncle Bill Bailey which will explain itself. I happened to be sitting beside that window next the shop yesterday noon and heard it start. So I gave Helen here the high sign and she took it down in shorthand. I wouldn't spy on 'em for a farm, but if you don't say it was worth while, I'll tear it up. Just listen good and proper while I read it to you.

"Say, Uncle Billy, what's all this stuff they call overhead?"

"Overhead, son—why overhead is what generally busts most mechanics who start in business—it busted me, all right, so I know."

"Why, you're the best mechanic in the shop, Uncle Bill. I don't see why you shouldn't make a lot of money in your own shop. Tell me about it, will you? I'm trying to study about overhead in night school."

"Being the best mechanic hasn't a darn thing to do with making money running a shop. Of course it helps get business, but the more business you do the more money you lose unless you are onto all the curves of that overhead you asked about.

"You see, son, there's a lot of things about running a business that the man in the shop don't think about. Can't think about them, of course, because he just naturally don't know anything about 'em. He ain't to blame, but he loses his hard-earned wad just the same when he starts in business for himself. And the trouble is he don't generally know just what hit him when the sheriff comes around and nails up his door.

"Now take this piston, son. Doesn't take much of a brain to know what the casting is worth. We both know that the labor cost is very low on these new machines. Jim and his gang, perhaps, total up to 10 cents per piston

for labor. Call the casting 15 cents and we have 25 cents, material and labor. Seems like highway robbery when we see that the old man lists them at $2. That's what I thought when I started. I wanted a *fair* profit on my work, so I put my price 'way down—and here I am back at work as a journeyman machinist.

"You see, son, we forget a lot of costs just because they don't stand out and bat us in the eye every time we look at a piston. Let's just suppose we make them on a lathe and a drill press and that we buy both machines for $1,000. Of course, they're ours and most of us think that as long as we don't pay rent or interest we can just forget 'em. That's mistake number one—and a big one.

"If we had borrowed that money at 6 per cent it could cost us $60 a year or $5 a month just to keep 'em. If we had put that $1,000 in the bank we'd get $20 a year, or $40 in a safe mortgage. Manufacturing isn't as safe as a good mortgage and ought to command a higher interest. For easy figuring call it 10 per cent or $100 a year.

"Then there's the rent of your shop and taxes, and believe me, the taxes count these days. Great and glorious victories cost real money when it's all over. Fire insurance and liability insurance for paying damages to your men have to be counted next. And these total up to a nice little sum. But they aren't the end by a long way.

"If you're running your own little shop you try to do all the clerical work. You order the material and chase it up over the phone or by mail or on your way to work. You open the mail and keep the accounts of money spent and received—when you don't forget it. And you're mighty apt to forget to put down a lot of things because your hands are greasy and you don't want to stop to wash up.

"In the beginning you also act as foreman even though

you do run a machine whenever you get a chance. But you never charge up anything for management—nor count the time when you are not at work on the machines. When you've added up all these things you find that labor and material are a small part of the cost in making a piston.

"In our case this shop has grown beyond the one-man stage long ago. The old man has to have clerks to open and sort the mail, clerks to enter the orders and make out orders for the shop. The purchasing agent has to keep track of the materials we need and buy them at the best prices he can get. He also buys tools and machines and the like.

"Then there's the planning department, which studies the best way of doing the jobs that come along, and the foremen and the superintendents. If you imagine we could get along without them, just think of what a job it is to keep things running straight in one department, let alone the whole shop.

"Every time a letter or a postal comes into the office, somebody has to look it over. Perhaps it's only a kid asking for a catalogue. Maybe it seems like a fool inquiry but it may develop into an order later. Perhaps it's someone raising very h—l because the shipping clerk didn't read the order right, left something out of the box, or maybe the customer himself made a mistake—they've been known to. Now, the old man can't look after all these, can't even answer 'em all. Has to have clerks and typewriters and dictaphones and filing cabinets and all that office junk you see. And somehow or other the girls and the boys in the office think they ought to be paid for what they do the same as we do. Of course we can kid ourselves that they ain't of much account and there's a lot of 'em ain't getting as much as you are, son, but we have to have 'em and they have to eat, same

as we do. And all that has to go onto the price of the pistons or motors or whatever. It's a part of overhead.

"Then there are the truckmen who get the stuff from the railroad and deliver the finished goods; the guys who keep track of the stock of bolts and nuts and things so we won't have to lay off the job; the telephone girl has to have money enough to keep her in gum and powder for her nose and perhaps a lipstick for Sundays and Wednesday evenings. And doggone it, son, they all think they earn real money.

"Once in a while, too, the old man gets a big order, and has to have money to pay for material and to keep us happy 'til the order is delivered and he can get his money. It runs into thousands and thousands of dollars and he has to borrow it from the bank and pay interest for the use of it. This and all the other things have to be paid for and the only way for the old man to get it is to tack the cost of these on top of labor and material.

"All these things go to make up overhead, son, and they make the original charges for cast iron and for labor look pretty darned small sometimes. Of course some shops have too much overhead. The system may be too complicated and take too many clerks. That's where real management comes in, knowing how to get enough system without getting it topheavy.

"There's another thing I haven't mentioned either, son, and that is, while $2 is the list price of that piston, the Johnson Motor Co. seldom gets the full two bucks. Dealers or repairmen have to live, you know, so they buy 'em for perhaps $1.50 or even $1.25. And even at that the old man would be tickled stiff if they would come with even a dollar bill and take 'em away. But no, he has to send out salesmen, to advertise in motor papers, to mail circulars, and spend real hard money to sell enough to keep us busy. And if we are not busy, we're unhappy

and the cost goes up, too, because all that overhead has to be charged up against fewer pistons.

"Gosh, son, it's most time to hear the whistle. Didn't know I'd gassed so long. But as I said before, I have painful recollections of what happens when you don't know all about tacking overhead onto your prices. Hope I've steered you a little in the right way, son. If not, come back at me tomorrow."

"Uncle Bill, you've saved my life on that exam at to-night's class. I was plumb flustered as to how to answer the questions. But you've put the whole thing so it's plain and clear. I'll sure knock 'em cold on that exam."

Old man Johnson quit reading and looked up. "Ever hear anything better than that? I'll say you didn't. And to think Bill Bailey has learned all that since he fizzled a few years back. I'd like to broadcast it from every radio station in the country 'til everybody understood it. Guess I'd be satisfied to get it across to all my own men even. I'd like to make Uncle Bill sort of shop tutor, but the minute I did every mother's son of them would say I'd bought the old man to spill my side of the story and so it must be bunk.

"I'm not altogether blaming them, Godfrey, but if they just knew about this darn overhead stuff, as Jimmie called it, they'd be happier and things would go smoother. I'm wondering what else Uncle Bill has up his sleeve."

And so I'm passing it on, because it seems so well worth while.

THE COST OF SUPERVISION AND OVERHEAD

In the days of the small shop there were fewer problems of every kind than face us today. The owner very often worked in the shop and the cost of supervision was almost negligible, as everyone but the apprentice could handle any job and usually needed neither instruction nor watching. The overhead cost could practically be summed up as shop rent and taxes, and these were as well known to the men in the shop as to the proprietor. Every man felt a proprietary interest in his machine and in his job, just as did the locomotive engineer of 40 years ago.

The growth of the industry changed all this. The element of personality disappeared and the absentee board of directors, like the absentee landlord, neither understood the problems of the men nor had their sympathy in any way. The old-time loyalty is almost impossible under such circumstances.

The newer type of manager, who had never been in direct contact with the shop, evidently did not appreciate the interest of the older men in their work. These managers adopted the attitude that, as long as the men were paid regularly and at the prevailing rate, they had no interest in anything beyond; in fact, that nothing else was any of their business. Coupled with this attitude came the advent of the huge combinations of business, many of them with capital stock full of water, of ostentatious display of wealth and other apparent evidences of huge profits.

The men in the shop knew the cost of materials

and of labor. Few of them, however, had reason to understand and to appreciate the increase in overhead expenses due to the changed shop conditions. The advent of the unskilled man on suboperation work added new problems in supervision and also added much to the overhead expense, and in this way offset, to some extent, the decreased cost of production due to the newer method. No attempt was made, however, to show this change in cost distribution to the men in the shop, and they naturally failed to grasp the great increase in the cost of supervision.

Although these huge combinations did not invade the machine-tool industry to any great extent, the influence has naturally been reflected in the minds of the men, so that many believe that it has become advisable for all manufacturers to explain matters to their employees and to show the various costs that go toward making up a modern business.

The change in selling methods, owing to the necessity of keeping the huge plants going as steadily as is possible, made another addition to overhead expenses which was unknown in the old days. Then the work came to the shop as it was needed. But the marketing of huge modern production requires a sales force that costs more than was formerly dreamed of. Yet, without it, the huge shop could not keep its production up to an economical point.

Had these changes been pointed out in heart-to-heart talks with the men, they would never have obtained the exaggerated ideas of profit that have existed in many cases. Many misunderstandings

could have been prevented and much greater harmony would have resulted.

There are grave questions as to how much overhead expense a business can carry legitimately, or when the cost of doing business becomes too great to warrant its continuance. There are some cases where the office in New York or Chicago employs as many people and costs more to run than the shop in which the products they sell are produced. In cases of this kind it is not surprising that the men who are actually making the product should question the kind of management or the kind of business that makes such a proportion necessary.

Much of the misunderstanding can be traced back to the teachings of the public schools, where, all unintentionally to be sure, children receive an entirely erroneous impression as regards costs and profits. This has been very clearly pointed out in a letter from a well-known manufacturer, who cites a well-known school example, which often reads about as follows:

"If a grocer buys a dozen oranges at 30 cents a dozen and sells them at 60 cents a dozen, what percentage of profit does he make?" The answer is, of course, 100 per cent. The damage is done by the incorrect use of the word "profit," and the child unconsciously absorbs the idea that the entire difference between cost and selling price is profit. Every business manager knows how incorrect this is.

It is to correct such impressions as these, as well as to assist managers themselves in determining the various costs that enter into the supervision of a

business, that we have secured expressions of opinion on this subject from a large number of machine builders. These are for the most part given without identification, at the request of the writers, and in the hope of securing further helpful data from others. It is the growing belief of many managers that, if proper methods of putting information of this kind in the hands of the men in the shop can be found, it will aid in the establishment of a better understanding, which means more harmonious relationships between the men and the management.

Where the Money Goes.—In order to get something of an idea of the many items that go to make up the expenses of a manufacturing business, perhaps the outline submitted by a well-known machine-tool company of the Middle West gives the most complete and at the same time most concise list. This divides the expenses into a number of headings, as shown, and shows very clearly how the various expenses are distributed. By this method they figure the burden or factory expense as being equal to the total of the material and labor cost on a complete machine; in other words, 100 per cent.

Factory expense is divided into two parts, as shown under the heading of Supervision and Shop Management. The first division includes that of supervision and other items which are quite different in character from those in the second group under the same head. This second group includes what might be called the material things that go into the machines being built.

Fixed Charges

Taxes, buildings and real estate, material and equipment, corporation tax, capital stock, street and sewer.
Insurance.
Depreciation on equipment.
Depreciation on buildings.
Interest on investment.

Office Expense

Executive and clerical.
Depreciation on furniture and fixtures.
Heat and light.
Bonus and wage distribution.
Interest on borrowed money.
Discount charges on customers' notes.
Interest paid on notes to creditors.
Supplies—printing, stationery, etc.
Donations—charity.

Supervision and Shop Management

Factory Expense

Executive: superintendent, production department, cost and factory clerks.
Purchasing department.
Watchmen.
Hospital.
Garage and trucks.
Discarded parts—old style.
Toolroom—manufacturing special tools and jigs; storing and distributing same.

Castings storage; receiving, storing, and issuing to factory.
Blacksmith, dressing, and hardening tools.
Stockroom—storing finished parts and issuing same to factory.
Steel stock storage; receiving, storing, and issuing to factory.
Shipping and boxing.
Drawing room.
Pattern shop.
Inspection department.
Millwrights and carpenters.

The foregoing departments each include the following expense items:

Fixed charges.
Power, heat, and light.
Labor.
Charges by other departments.
Defective workmanship.
Repairs.
Bonus and wage distribution.

The monthly total of the entire general expense is distributed on a productive-hour basis and charged as such to each productive department.

The productive departments are classified as follows:

Boring and chucking.
Lathes.
Grinding.
Polishing.
Large erecting.

Drilling.
Milling.
Planing.
Painting.
Small lathe erecting.
Milling-machine erecting.
Automatic screw machines.
Rack-cutting and keyseating.
Cutter grinder assembling.
Countershaft assembling.
Boring mills.
Gear cutters.
Repair department.
Unit assembling.

The above include the following expense items:

Fixed charges.
Power, heat, and light.
Nonproductive labor—foreman and assistants.
Charges by other departments.
Defective workmanship.
Supplies.
Repairs.
Bonus and wage distribution.

Total department expense is distributed on a department productive-hour basis, and by adding the general factory expense hourly rate we have the complete hourly burden rate.

Selling Expense

Fixed charges.
Executive and clerical.

Bonus and wage distribution.
Discount allowed customers.
Collection charges on discounted notes and checks.
Entertaining.
Club dues.
Traveling expense.
Publications.
Catalogues and circulars.
Freight and drayage.

Selling expense is added to the total cost. The burden (or factory expense) on a complete machine is equal to the total material and labor cost on same.

In addition, the manufacturer pays, this year, an excess-profits tax which in large concerns is about 75 per cent.

Taxes Make Overhead 200 Per Cent.—The second concern reports, according to figures recently compiled for 1918 operations,

Our overhead was almost double the average hourly rate of shop employees. This, of course, was largely due to the tremendous income tax which the form of our organization imposed on us last year.

Firm No. 3 writes as follows:

We figure the cost of supervision in shop management as two separate burdens; one called the manufacturing expense and the other the commercial and sales burden. The kind of accounts that are carried under each of these heads would be those naturally suggested by the titles.

The total manufacturing expense for the month is divided by the total number of productive hours for a month and the results given as a productive hourly burden rate.

We do not consider this necessarily the best or most accurate method, inasmuch as it throws the cost of handling of raw material into the productive operation. It is, however, the method which was instituted here some time ago and we continue it for the sake of comparisons with past records, and it works out very satisfactorily. The sales and commercial burden is estimated as a percentage of the cost of sales. Both of these burdens are subject to considerable fluctuation and for the sake of obtaining more practical comparisons, we are in the habit of establishing a fixed burden for a period of six months and then adjusting it to take care of an excess or deficiency which may have accrued.

Need of Understanding.—No. 4 says:

I quite agree that the question of management and supervision is perhaps the one phase which is least understood by the average worker. I also believe that a certain amount of educational work along these lines would prove interesting and helpful, for I cannot help feel that, if the average worker really understood more fully and definitely the many and varied business perplexities which daily confront the manufacturer, it could not fail to have a beneficial effect on their relations. It is a fact that very few workers have the slightest conception of what the word "overhead" means when applied to the cost of manufacturing, and it is also to be deplored that so many manufacturers seem to have so little idea as to what does or what should constitute their overhead.

In the old days, "overhead" was not a very common term. In fact, "operating" expenses or "running" expenses were the terms employed. But after the so-called efficiency engineers began to permeate the country, a good

many new terms and phrases (both English and profane) seemed to come into being, and overhead was one of the more expressive, which has in too many cases been badly overworked.

Naturally, the cost of supervision is but one item that goes to make up what is known as overhead. In the matter of supervision, it is our practice to handle the cost in such a way that the expense of supervision of one department does not add to or detract from the expense of any other department. Of course, in the final analysis the cost of supervision goes in the general item of operating expenses. To this is added all items of general expense, such as insurance, taxes, interest on capital, advertising, and all nonproductive labor that is not directly or indirectly associated with the factory cost of production.

In the old days it was considered almost a crime if the factory superintendent did nothing but superintend. He was expected, not only by his men but by the management as well, to turn out a full day's work, and the superintendent was usually recognizable from his oversoiled appearance, being always the dirtiest one of the bunch. It was, however, finally discovered that a superintendent could greatly increase production by spending all of his time in directing the operations of others and by using his brains instead of his hands in the direction of better methods for production.

It was later found desirable to divide the work into departments, to analyze the cost of production in each department, and in fact, to systematize methods, and, through efficient department foremen, carry on a system of continuous study for betterment in all directions toward an increased production of better quality. In every case where modern methods of shop supervision have been introduced, production has been bettered and increased, while the overhead has been very greatly re-

duced as compared with the proportionate increase of production.

In line with an increased production comes the matter of better working conditions and the welfare of the worker, for we cannot fail to recognize that we can all accomplish more and better work under proper conditions of light, cleanliness, and order. Consequently, we endeavor to maintain the most sanitary, light, and healthful atmosphere in and about our works and offices. The maintenance of such conditions adds to the overhead, but we find that it helps to produce a better product and stimulates production to a degree that more than compensates for the expense.

I have known manufacturers who inventoried their plant year after year as a constant factor. Every machine was inventoried at its original cost, regardless of its years of service, no depreciation being figured. Their yearly sales, with cash on hand or deposit added to the inventory, constituted their gross worth. By deducting their running expenses, which included supervision, taxes, and insurance, it produced their net worth, and their year's profit was figured as the amount of money on deposit over and above what was on hand at the same period in the previous year.

These manufacturers still have "working foremen" and are unable to understand how a superintendent or foreman who does not produce with his hands can be of any real service. Of course, in such firms the general manager always does the shipping and invoicing in order to earn his wages and to ensure that no mistakes are made! Fortunately, these firms are growing less in number, but the real overhead of these firms is considerably in excess of that of a modernized works with proper supervision.

It is our practice to relieve the worker from all clerical work so that each man's time and attention can be de-

voted to production without having to disturb himself several times each day in trying to figure out whether he put in three hours on the last job and an hour and a half on the job before. We issue work tickets from our factory office by means of a pneumatic tube system connected with each department, and by which work "move" tickets and all other departmental instructions are issued, so that the worker is enabled to keep his mind on production.

This, of course, adds to the overhead, but not in proportion to the time that it saves the workers and the increased production effected thereby. Anything that will save time, add to the betterment of working conditions, remove complication and detail, is a factor in the contentment of the worker. It adds to his efficiency, ensures a better product and an increased production in a measure beyond the extra burden to the overhead which such betterment incurs.

As to the cost of supervision, we divide up our overhead under four different items. These are factory burden, commercial burden, direct labor, and material. These for the past year show about as follows: factory burden, 45.8 per cent; commercial burden, 6.3 per cent; direct labor, 17.4 per cent, and the material, 30.5 per cent.

Believes in Giving Facts and Figures.—No. 5 writes:

We hope that managers and executives will realize the necessity of carrying on educational work among their own employees so as to give labor in general some definite facts and figures regarding the cost of doing business.

The writer believes that a considerable amount of the present unrest in the industrial situation is caused by ignorance on the part of the average shop worker regarding

the cost of supervision and other necessary expenses, these expenses being always necessary to hold an organization together and to procure work for which wages may be paid.

As a general proposition, we believe that almost any management will be benefited by taking the workers into their confidence and explaining the items making up the cost of overhead. If this is done in some simple form so that the workers will at least grasp the fundamental principles, we believe that they will clearly understand that all between the cost of material plus direct labor and selling price is not profit.

The writer has even met intelligent foremen who did not have any clear conception of overhead expense or of the way in which this expense must be taken care of, so that a profit can be ensured for the capital invested. We believe also that some additional benefit would be derived in letting the workers know about the actual cost of the materials they use or waste, and the first cost and subsequent expense for repairs of the equipment which is provided for them. For without this they would be unable to exercise their skill and thus secure any income.

Where Labor Cost Is High.—No. 6 is from a shop building small machine tools, and says:

As the machinery we build is of small size, the labor cost is by far the largest item. As our men are all paid on the hourly basis, we have taken the productive hour as the basis of all our overhead charges. In other words, we have recorded the number of hours that our productive men have charged in during the past year and have then divided the factory burden, which includes the non-productive labor, all supplies used in the manufacture of the machines but which do not enter into their construction, depreciation on buildings, machinery, tools,

patterns, and drawings, insurance, light, power, heat, repairs, and renewals to the buildings, cartage, freight, express, and taxes. This, we find, amounts to 13½ cents per hour.

In addition to this, we have figured the sales expense, including in it the general and office expense, advertising, commissions, and items of a like nature. This amounts to 6½ cents per hour and makes a total of 20 cents to be added to each hour of productive labor required in the manufacture of a machine. We consider that this 20 cents multiplied by the number of hours used in producing a machine, added to the actual wages paid to the men and to the cost of materials, represents the total cost, and that this is the least which must be obtained for the machine to ensure against actual loss.

The profit on the transaction should include the interest on the capital invested and the salaries of the proprietors if they are actively engaged. In order to allow for expansion of the business, a larger profit than this must be allowed for.

High Wages but Lower Labor Costs.—Among the most interesting figures are those obtained in letter No. 7, which, after indorsing the plan for the distribution of real knowledge concerning costs of production, gave an excellent summary of their own distribution of costs during the years 1913, 1914, 1917, and 1918. These are shown in the following table and should be extremely valuable as a means of comparison, as this is a modern shop and one that is recognized as being well managed.

It is particularly interesting to note the difference in the percentages of the various items during the different years. Material, mostly cast iron in this

case, fell from approximately 25 per cent of the total cost in 1913 to 17 per cent, in 1914, but jumped to over 38 per cent in 1917. This was during the time of $55 pig iron. When the price was controlled by the War Industries Board the cost of material dropped to less than 35 per cent.

Cost of Product in Percentage

	1913	1914	1917	1918
Material	0.2512	0.1695	0.3847	0.3471
Productive labor	0.2233	0.1735	0.1937	0.1649
Burden or shop overhead	0.4086	0.4781	0.3708	0.3615
Commercial cost	0.1167	0.1781	0.0507	0.1264

Productive labor was less in 1914 than in 1913, and though it increased slightly in 1917, the lowest cost is in 1918, when wages were higher than at any other time. This speaks particularly well for the productive methods and probably for the cooperation secured in the shop. It is also interesting to note that the burden or overhead expense was lower than at any previous time, this being particularly high in 1914. Commercial or selling costs were extremely low in 1917, owing to practically the entire product being absorbed or at least allocated by the governmental activities.

Firm No. 8 expresses its approval of the publication of facts concerning the amount of overhead, saying:

The average workman has no appreciation of the cost of doing business and also an exaggerated notion as to

profits. We believe that if the returns of corporations, which are open to the public in Massachusetts and other states, were carefully studied, they would show that for a long term of years profits did not average nearly as much as was popularly supposed.

Our own cost-account system is very common. We keep the total of the productive hours in each department, find out weekly the total of the various items of overhead expenses, and divide this by the number of productive hours, then distribute the cost of the overhead to the various jobs in accordance with the number of productive hours on that chart. The cents per hour will, of course, vary according to the number of productive hours at which the shop is running. Our present figures are somewhat over the normal, owing to the fact that we have been doing an unusual amount of repairing which we have charged to this account.

Having established our manufacturing costs, we keep the cost of selling and of general administrative expense for each group of the articles we manufacture. This total we distribute as a percentage on sales in the corresponding department.

Certain fixed items as, for example, a requisite return for capital, are somewhat beyond the control of the men. For without a return of say 6 per cent on the investment, there would be no capital for expansion or extension of the business.

The matter of taxation is one in which all workmen have a part, and it is a matter of good citizenship for every voter to see that the money raised in taxes is properly spent. City taxes in our case amount to about ½ cent an hour on productive labor, state taxes perhaps ¼ cent, and the Federal taxes about 2 cents per productive hour. This should make it evident that any extravagance in government leaves less money for the develop-

ment of the business or to be distributed between those who invest and those who directly produce the work of the shop.

We believe that there should be a frank understanding as to the costs of doing business and that an effort should be made to have the men realize that the responsibility for results is partly theirs. Anything which can bring about a better understanding of the problems on both sides cannot fail to make for more harmonious relations and better returns to all concerned.

These firms represent a wide variety of machine manufacture, and the figures given may be considered to give a fair average for present conditions. It is almost universally suggested that the facts about shop costs should be made clear to the workmen. Clearly written bulletins or posters may be the best method of doing this.

These extracts are given not to discourage starting a small shop but to show the problems involved in order to aid in avoiding the mistakes that cause too many failures.

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